Vol. IX. — No. 6. June 1927.

BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[725 .33 (.493)]

The equipment of the new locomotive depot at Schaerbeek-Formation,

By A. CHANTRELL,
ENGINEER OF THE NATIONAL RAILWAY COMPANY OF BELGIUM.

Figs. 1 to 48, pp. 458 to 507.

An article in the December 1924 number of the *Bulletin of the Railway Congress* reported the opening of the new Locomotive Depot at Schaerbeek-Formation, and briefly described the equipment of the depot, part of which was still in course of construction. It will now be interesting to look into the practical advantages obtained, and the savings effected and, in addition, to determine the influence experience of Schaerbeek will have on future layouts. At the same time some of the methods which were only briefly mentioned in the former note will be considered in greater detail.

I. — Shed building and arrangement of the yard.

a) *Layout of the shed.* — The shed (figs. 1 and 2) is of the type with parallel tracks : the large sheds of the Belgian System are almost exclusively rectangular. The building is made up of two sheds, each with 19 dead-end roads, each with its own holding sidings and separated by the machine shop and smithy. The size required was obtained by making the sheds rather long : each covered road holds 4 or 5 engines according to type.

Rectangular sheds are the simplest and cheapest in first cost : they hold the maximum number of engines for the surface covered. For sorting out the engines and getting them away they have none of the advantages of the shed with converging tracks. To be logical, it ought to be possible to take any locomotive out of the shed without hindrance or extra shunting; with rectangular sheds the engines would have to be stabled in the order they were required for use. This is the more easily done the fewer engines there are in the shed; the most unsatisfactory shed is one of considerable length with one out-going road, as at Schaerbeek. Many shunts have to be made before the engine required, usually at the far end of the shed, can be got out. When first put into service the number of shunts was as many as 80 a day of 24 hours, requiring the whole time use of a powerful shunting engine with a gang, consisting of a leading shunter, a man for coupling, and

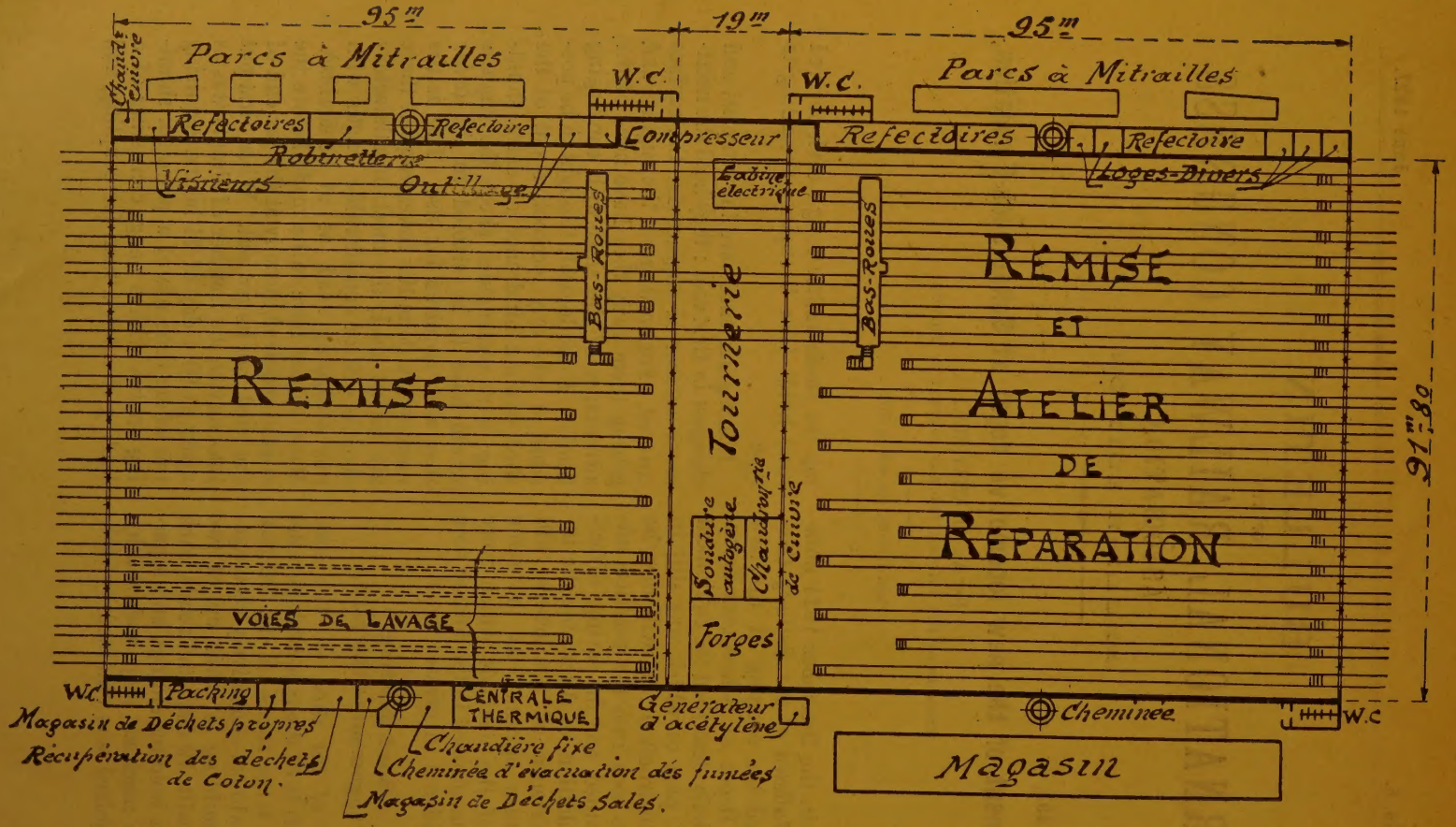


Fig. 1. — Arrangement of Schaerbeek-Formation depot.

Explanation of French terms: Bas-roues = Wheel drops. — Cabine électrique = Substation. — Centrale thermique = Central heat recovery plant. — Chaudière fixe = Stationary boiler. — Chaud^{r} cuivre = Copper smith. — Chaudron^{rie} de cuivre = Copper smiths. — Cheminée = Chimney. — Cheminée d'évacuation des fumées = Stack for removal of fumes. — Compresseur = Compressor. — Forges = Smithy. — Générateur d'acétylène = Acetylene generator. — Loges-divers = Various shops. — Magasin = Stores. — Magasin de déchets propres = Store for clean waste. — Magasin de déchets sales = Store for dirty waste. — Outillage = Tool room. — Parcs à mitrailles = Scrap bins. — Récupération des déchets de coton = Waste recovery plant. — Réfectoires = Mess rooms. — Remise = Shed. — Remise et atelier de réparation = Shed and repair shop. — Robinetterie = Brass finishing shop. — Soudure autogène = Oxy-acetylene welding. — Tournerie = Turnery. — Visiteurs = Inspectors. — Voies de lavage = Washing out roads.

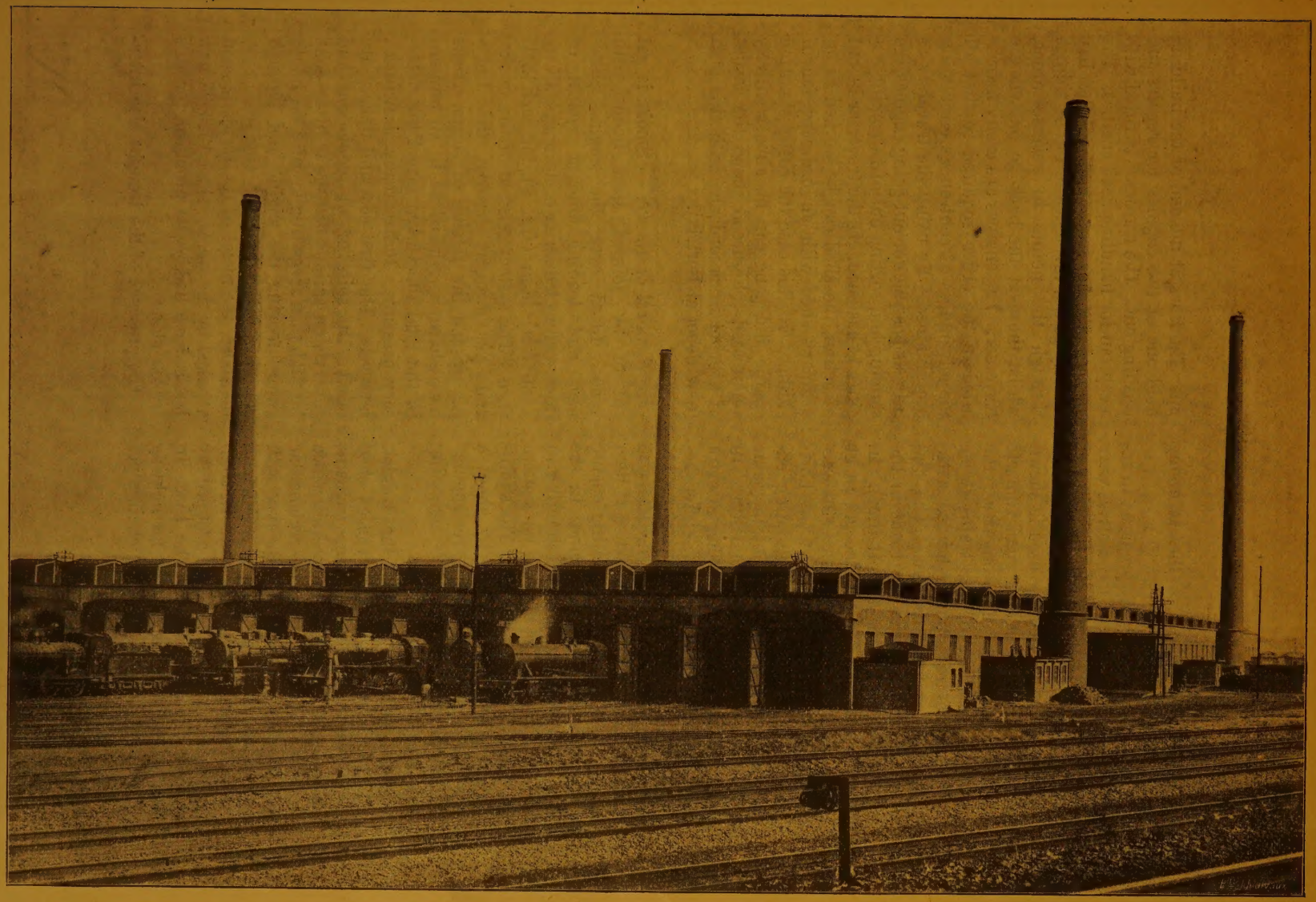


Fig. 2. — Schaerbeek-Formation shed.

a labourer to attend to the reversing gear per shift of 8 hours.

A list was subsequently prepared in accordance with which the locomotives were put on prescribed lines, and the number of shunts was reduced to about 50 a day. The *classification diagram* used is shewn in figure 3. Conventional signs indicate the different types of locomotives; the numbers are those of the trains to be worked; each train double-headed naturally requires two positions. The diagram can also apply to the roads in the yard (engines standing a short time). In order that the engines can be got in or taken out without extra shunts, the vertical lines through the ends of any horizontal line, representing a standing engine, must not cut any mark of the same kind below the said horizontal line. In spite of this method, the number of extra shunts continued to be high, either because the engines came in late, or because want of room made it necessary to stable an engine on a road when it then blocked in others. The shunting engine formerly used to shunt engines in the shed only, now has to do all shunting in the depot, as well as to place the bottom door wagons at the coal stage. The shunting gang has been reduced by about a third. None the less, the long rectangular shed involves relatively high operating costs for sorting out engines.

In consequence of this, the Belgian Railways have adopted the type of shed with traverser and fan of sidings (scheme, fig. 4) for all important sheds built since the war, as in this way the rectangular shed has the same merits as the type with converging lines, so far as safety and ease of shunting are concerned. In coming engines are stabled and grouped by means of the traverser. The space in front of the traverser is used for lighting up, and can hold two or three engines per pit. The lines at the end of the building hold one or two engines for repairs and washing out. The traverser is fitted with a capstan for handling dead engines. The engines at the front end of the bay usually go out through the fan of sidings through the points in reverse order, whilst those at the back go out via the traverser. The engines are easily marshalled in the order required so that all the advantages of continuous circulation are obtained. By using the traverser as little as possible for out-going engines, the stabling and sorting out of in coming engines is hastened. If the traverser be out of action, the shed can be worked as an ordinary shed with an ordinary fan of sidings. In this case the costly shunting engine and gang can be almost entirely suppressed. Figure 5 shews the layout of a depot in accordance with this plan (new depot at Bertrix).

b) *Removal of smoke.* — Smoke is got rid of by jointed steel hoods with vanes, fitted over the engine chimneys and leading into a system of ducts connected to two chimneys 55 m. (180 feet) high (fig. 2) for each half shed. The system gets rid of the smoke, and the draught hastens the lighting up and the raising of steam. Tests have shewn a gain of 30 to 40 minutes in the total time taken to get the necessary pressure. It has many drawbacks, however. The first cost and upkeep are heavy. In spite of all regulations and supervision serious damage is often done through men forgetting to raise the hoods before moving the engine and through shunting into stationary engines. Furthermore, the metal of the hoods is soon attacked by the smoke; since 1923, 35 new hoods have had to be provided for this reason alone.

The presence of the troughs also inter-

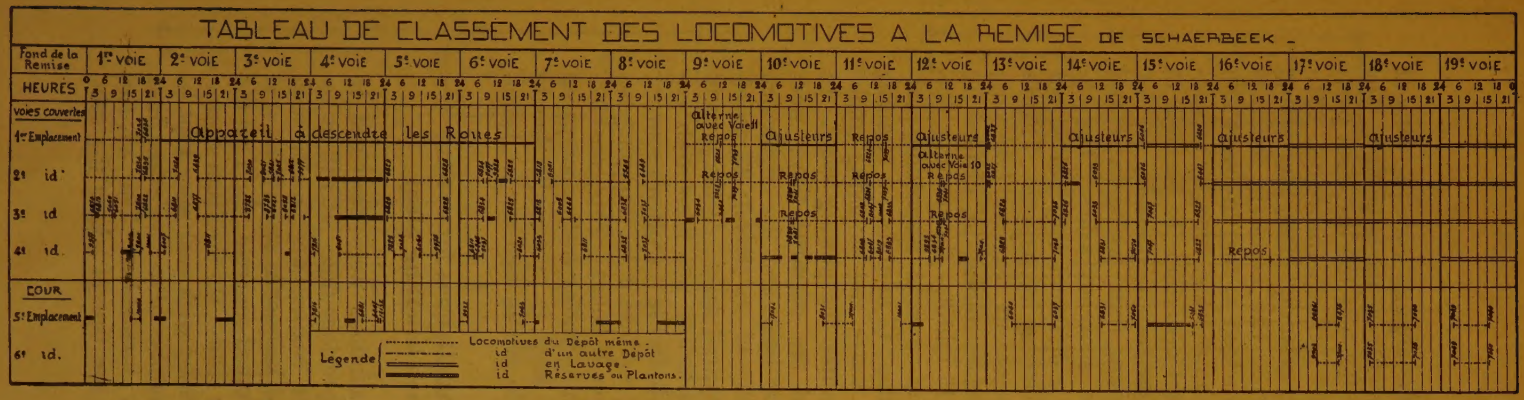


Fig. 3. — Table of grouping of engines in the shed at Schaerbeek.

Explanation of French terms : Ajusteurs = Fitters. — Alterne avec voie = In turn with road. — Appareil à descendre les roues = Wheel drop. — Cour = Yard. — Emplacement = Stall. — Fond de la remise = End of the shed. — Heures = Time. — Légende = Explanation. — Locomotives du dépôt même = Locomotives belonging to the depot. — Locomotives d'un autre dépôt = Locomotives belonging to another depot. — Locomotives en lavage = Locomotives being washed out. — Locomotives réserves et planton = Locomotives spare or service. — Repos = Stopped. — Voie = Road. — Voies couvertes = Covered in roads.

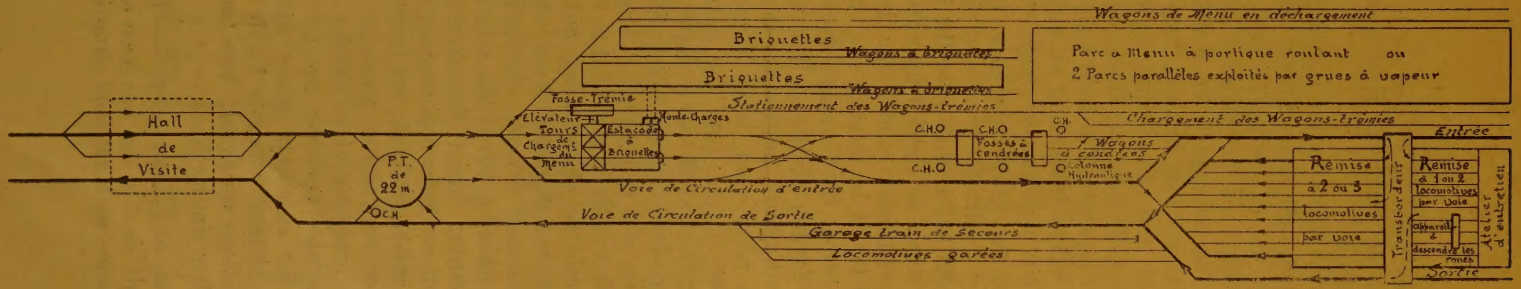


Fig. 4. — Layout of a depot with rectangular shed with traverser

Explanation of French terms : Atelier d'entretien = Repair shop. — Chargement des wagons-trémies = Loading hopper wagons. — Colonne hydraulique (C. H.) = Water column. — Élévateurs = Elevators. — Entrée = Way in. — Estacade à briquettes = Briquette stage. — Fosses à cendrées = Ash pits. — Fosse-trémie = Hopper pit. — Garage train de secours = Break-down train siding. — Hall de visite = Inspection shed. — Locomotives garées = Spare engines. — Monte-charges = Elevator. — Parc à menu à portique roulant ou 2 parcs parallèles, etc... = Stack of slack coal with goliath crane or two parallel stacks worked by steam cranes. — P. T. de 22 m. = 72 ft. 2 in. turntable. — Remise de 1 ou 2 locomotives par voie = Shed for 1 or 2 locomotives per track. — Remise de 2 ou 3 locomotives par voie = Shed for 2 or 3 locomotives per track. — Sortie = Way out. — Transbordeur = Traverser. — Voie de circulation d'entrée = In coming track. — Voie de circulation de sortie = Out going track. — Wagons de menu en déchargement = Wagons of slack coal for off loading.

feres with the lighting of the shed. If the hoods are defective the glazing soon becomes blackened.

As engines in steam or for lighting up have to be put under the hoods, much room can be wasted owing to the difference in length of the engines being stabled. On an average 3 to 4 metres (10 to 13 feet) are lost between two engines, or, for the three spaces, 9 to 12 metres (30 to 39 feet) per track, which would usually be enough to hold a shunting engine. When inspecting an engine or carrying out repairs, the engine has to be got into the proper position; it is then necessary to lift the hood and move the engine, both before and after the job. The engine cannot be lighted up until it has been moved back under the hood which can delay it in leaving the shed.

For these reasons the Company decided to equip no further sheds in this way. In sheds recently built continuous smoke troughs have been used, built of reinforced concrete boxed into the special girders of the roof, as shewn in figure 6. The long hoods lead into chimneys fitted with aspirators, also in concrete. A steel cap fitted with a cable is provided so that each hood could be closed when out of use. The Chanard aspirators have round the central chimney *C* seven rectangular passages narrowing towards the exterior. The wind coming from the direction shewn only enters the two diverging passages *A*, and smoke is drawn out through the five other converging passages *B*. The Schepens aspirator gives similar results by a suitable opening out of the top part of the chimney, above which three conical shaped concrete hoods of suitable dimensions are fitted. The Aeros aspirators follow similar lines.

c) *Arrangement of the yard.* — The yard of the half shed in use has been laid out in accordance with rational shunting principles; the engines come in without return movements on the same line. The engines pass through the different parts of the depot : turning, inspecting, coaling, sanding, cleaning fires, and taking water in turn. The necessary facilities have been provided so that the work can be done in the shortest time, by arranging for several operations to be done at the same time where possible, as, for example, cleaning fires, taking water, and emptying the smokebox ashes. The engines go out a different way and do not cross the in coming locomotives. Thanks to this arrangement, engines take only 35 minutes when coming in, divided up as follows : 15 minutes for turning, taking in lighting up wood, inspection, coaling and sanding; 15 minutes for cleaning fires, taking water and emptying smoke boxes; 5 minutes for putting away. In the old shed the required times were three times as long, and the enginemen had to be relieved on arrival; 25 reliefmen were required daily. At the present time the enginemen put their own engines away. Relief is not often required, 6 men being sufficient for the purpose, 2 per gang per 8 hours. This considerable saving in operating cost as compared with the old shed is principally due to the speed with which coal can be taken.

II. — Installations for coaling and ash handling plant

These installations were described in detail in the previous note. It will be recalled that the engines were coaled with slack coal and briquettes at a raised coal stage in reinforced concrete (fig. 7) at the two incoming roads. On the stage a number of tubs filled with coal were kept in reserve on a number of narrow gauge lines connected by turntables. Two of the lines lead to the tips at which the tubs

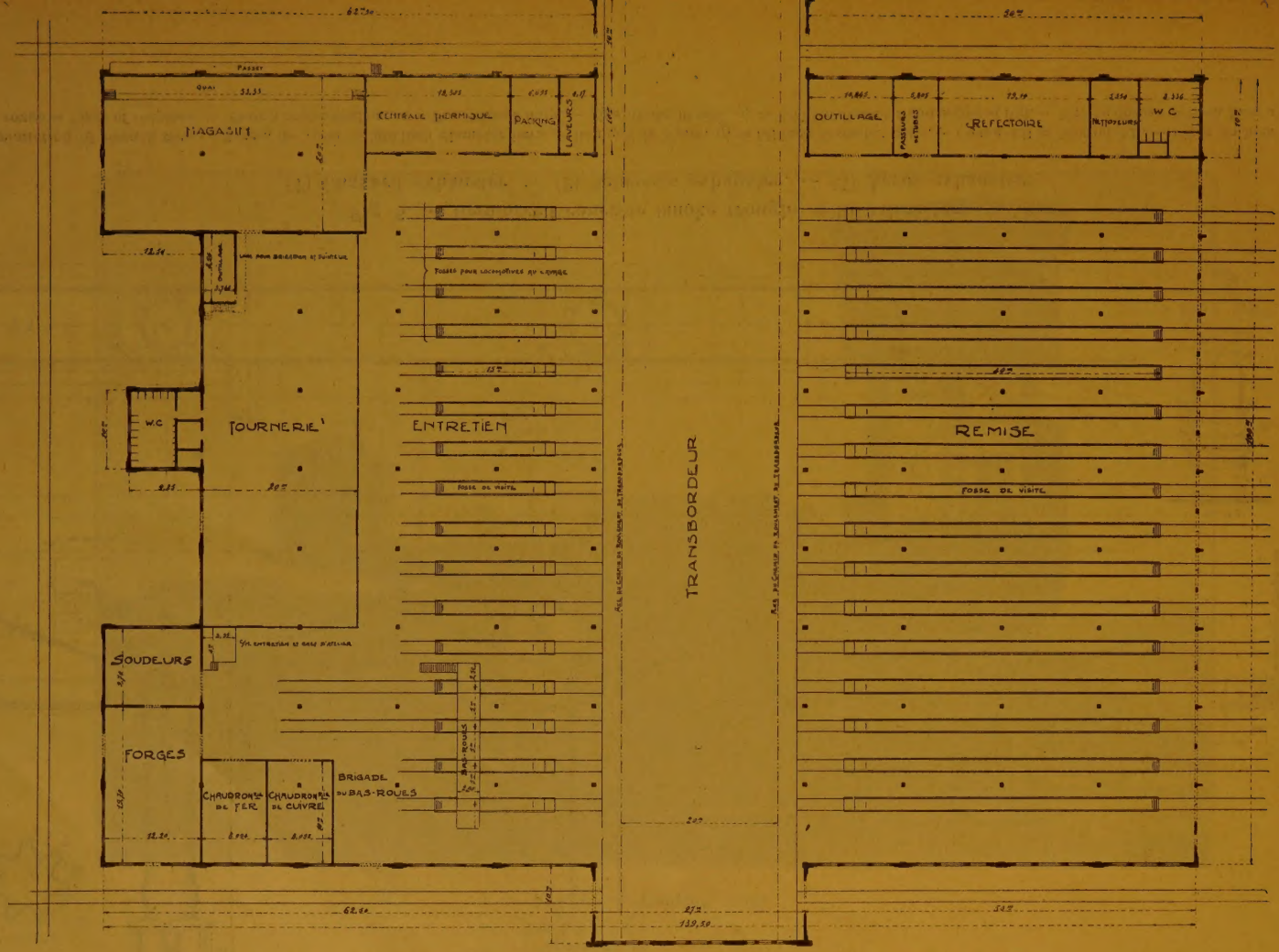


Fig. 5. — General arrangement of a shed with traverser (new shed at Bertrix).

Explanation of French terms : Axe du chemin de roulement du transbordeur = Centre line of traverser runway. — Bas-roues = Wheel drop. — Brigade du bas-roues = Wheel drop gang. — Centrale thermique = Heat recovery plant. — Chaudronnerie de cuivre = Copper smiths. — Chaudronnerie de fer = Boiler shop. — C/M entretien et chef d'atelier = Foreman of repairs and shop foreman. — Entretien = Repairs. — Forges = Smithy. — Fosse de visite = Inspection pit. — Fosses pour locomotive au lavage = Washing out pits. — Laveurs = Washers out. — Loge pour brigadier et pointeur = Charge hand and marker off. — Magasin = Stores. — Nettoyeurs = Cleaners. — Outillage = Tool room. — Passeurs de tubes = Tube shop. — Quai = Platform. — Réfectoire = Mess-room. — Remise = Shed. — Soudeurs = Welders. — Tournerie = Turnery. — Transbordeur = Traverser.

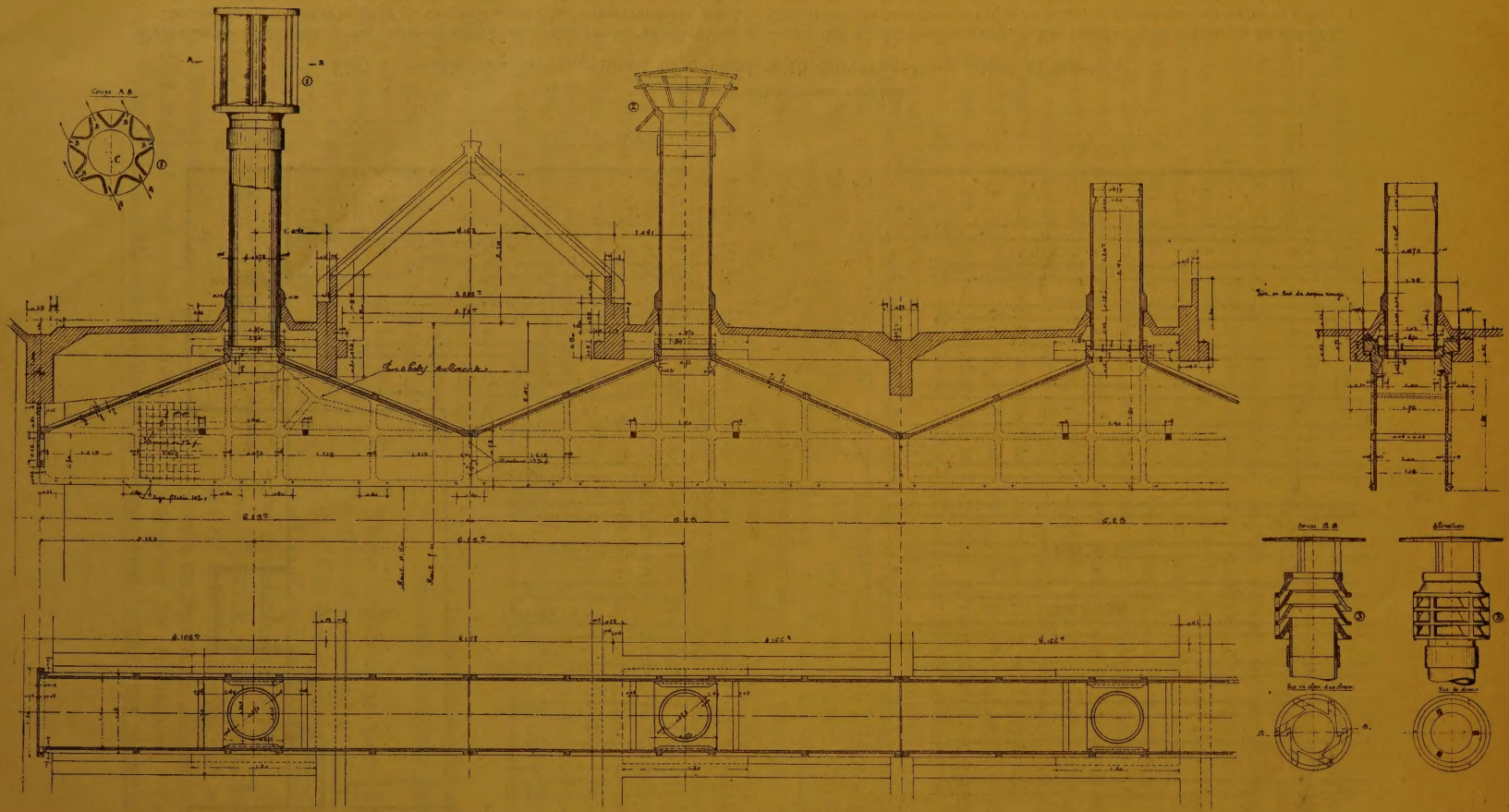


Fig. 6. — Reinforced concrete smoke troughs with exhausters.
(1) Chanard exhauster. — (2) Schepens exhauster. — (3) Aéros exhauster.

Explanation of French terms : Barres de 5 mm. = 3/16 inch diameter bars. – Boulons de 5 mm. ∅ = 5/8 inch diameter bolts. — Coupe AB = Section AB. — Pièce de bois de sapin rouge = Piece of red wood — Pour 3 hottes seulement = For 3 hoods only. — Tige filetée 10 mm. ∅ = 3/8 inch diameter end screwed rod. — Vue de dessus = Seen from above.

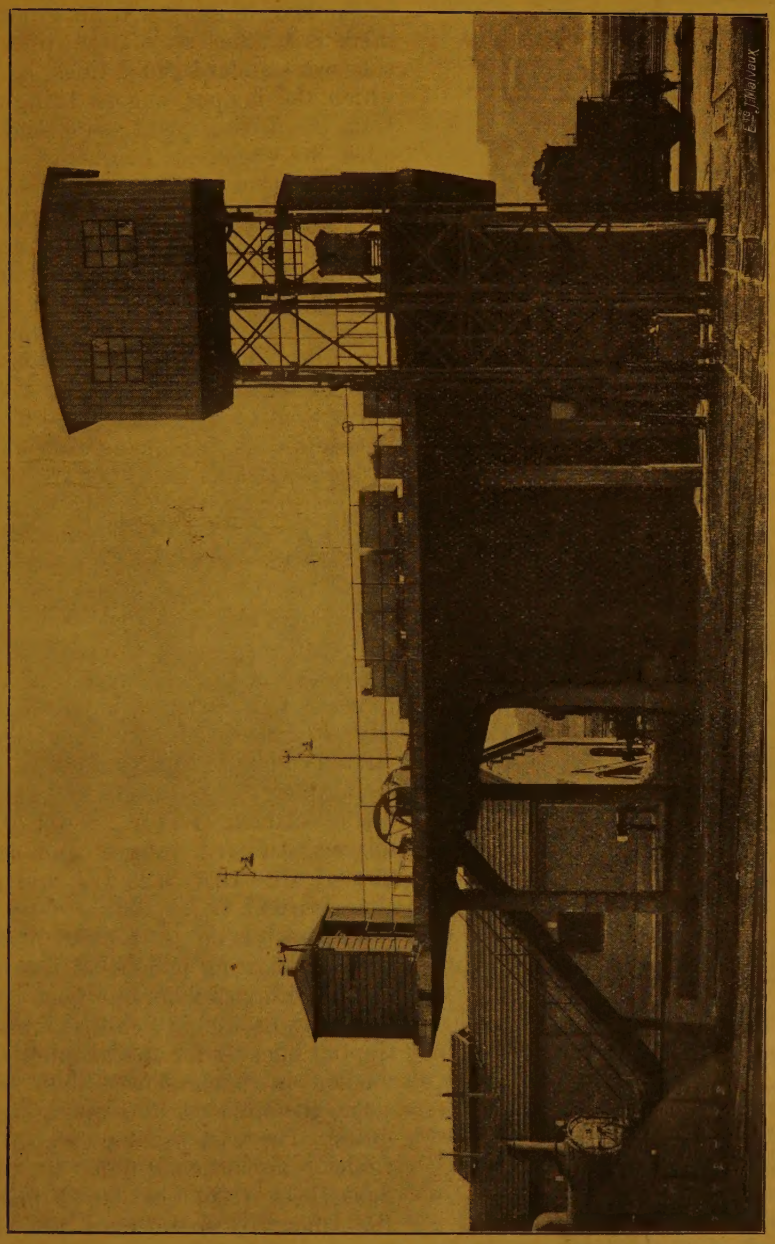


Fig. 7. — Coaling stage.

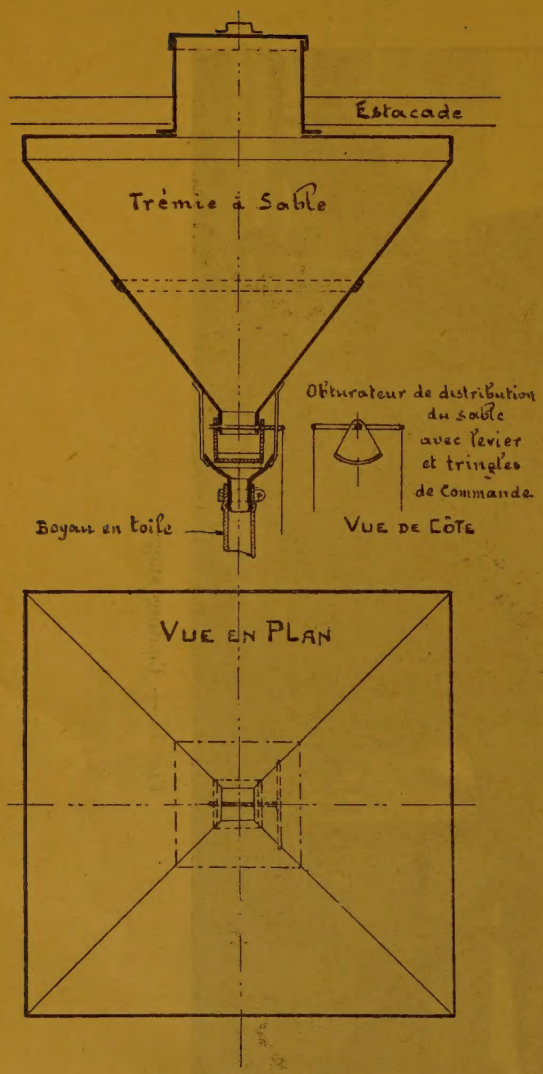

Estacade
Trémie à Sable
Obturateur de distribution du sable avec levier et tringles de Commande.
Boyau en toile
Vue de Côté
Vue en Plan

Fig. 8. — Sand hopper.

Explanation of French terms: Boyau en toile = Canvas pipe. — Estacade = Stage. — Obturateur de distribution du sable avec levier et tringles de commande = Lever and rod operated sand supply valve. — Trémie à sable = Sand hopper. — Vue de côté = Side view. — Vue en plan = Plan view.

were emptied on to the tenders. At the opposite end of the stage two lines are provided for the loaded tubs brought up by the two elevators. At the ground level there is another set of tram lines alongside two standard gauge lines, on one of which the hopper wagons bringing coal from the mixing plant stand, and on the other the wagons of briquettes.

The stage was also used for supplying sand to the engines. Steel hoppers (fig. 8) were provided on the stage, and are filled from special tubs which bring dry sand from the furnace, and are raised up to the stage by the elevators. The sand boxes are filled through canvas pipes. The flow of sand is controlled by a valve in the bottom of the hopper operated by a lever and rods. Above each incoming line three hoppers of this kind are provided, one on the centre line for engines with sand boxes on the barrel, the others on the two sides of the line for engines with sand-boxes on the footplate.

As stated above, this coal stage met the requirements, so far as speed of coaling was concerned; the average time is 1 minute per ton. In 1926, the average quantity of coal used daily was 300 tons, 60 tons being briquettes. The *cost* of labour per ton was 2.20 fr. This price includes labour (1.55 fr.), power (0.06 fr.), upkeep (0.06 fr.), interest and depreciation of first cost (0.26 fr.), and general charges (0.27 fr.).

In some sheds of the size of Schaerbeek, the coaling is done with two steam cranes with grabs, for the slack coal, and one or two stationary electric cranes with tipping buckets for the briquettes. This method is much slower than the coal stage, the time per ton averaging 3 minutes. The cost per ton is also higher. Under similar conditions to those at Schaerbeek (300 tons, 20 % briquettes) the labour is more than 20% higher; the cost of fuel for the cranes is 0.50 fr. per ton handled; the cost of interest and

depreciation is roughly equal to that of the stage; the upkeep is more costly, and the total cost per ton with steam cranes amounts to about 3 fr.

Coaling towers for coaling slack in conjunction with a stage for briquettes reduce the cost of labour by half, but the first cost is about three times greater.

Fig. 9. — Schaerbeek shed. — Ash handling plant.

For the same output as at Schaerbeek with a plant of this kind the cost is about 2 fr. per ton, which is rather less than with a coal stage. The Belgian Railways have decided to use this type of coaling plant for its new large sheds.

From these figures it will be seen that when coal is sent to the depots in hopper wagons, a raised coal stage is a simple and inexpensive way of rapidly handling coal and briquettes for outputs of 100 to 300 tons a day usual in Belgium. The cost of coaling towers and a coaling stage for briquettes can only be justified from a financial point of view when the consumption is relatively high.

The *ash handling plant* (fig. 9) consists of two groups of pits of large capacity, arranged in parallel one to the other, and able to hold 8 locomotives at once. Each group of two pits is served by a loading appliance, consisting of a steel framework supporting a track, on which runs a cradle carrying a grab. The grab holds 1 m^3 (1 1/3 cubic yards). At Schaerbeek the drums controlling the cradle and the grab are at ground level. In more recent plant, the frame is built like a goliath

crane with a cabin for the driver (fig. 10) and the output has been increased. The plant at Schaerbeek is quite satisfactory. The cost per ton handled was 1.90 fr. in 1926 : this includes (0.48 fr.) for labour, (0.12 fr.) for power, (0.31 fr.) for upkeep, 0.90 fr.) for interest and depreciation of the capital, and (0.09) for general charges.

Fig. 10. — Ash loading plant — recent design.

III. — Hot water washing out plant, Micheli system.

In the previous article the general working of the automatic washing out and hot water filling plant was described, and particulars given of the method of recovering the heat in the water from the boilers washed out. Figure 11 shews the plant at Schaerbeek with the pipe lines for the water recovered, both when the boiler is under pressure and

when the boiler containing hot water is not under pressure and is emptied by a centrifugal pump. Figures 12 to 18 shew the arrangement of the various parts which will now be described in more detail.

A. — Description and method of operation of the plant.

Figure 1 shews the five roads in the shed set aside for washing out the boilers, and the covered pits between the lines, in which are the three lagged pipes : one for the dirty water, the second for the hot washing out water, and the third for the hot water for refilling. The pipes are fitted with stop cocks with unions for flexible pipes.

a) *Emptying the boilers.* — The boiler to be washed out is connected to the blowing down main, and the water under pressure passes through a *separator S* with a sieve (fig. 19) which prevents any dirt or scale from reaching the heaters *R*; the dirt is periodically emptied through a cock provided.

When the *two-way cock r* is in the blowing down position under pressure (normal position) the water passes straight to the *heaters R*, and at the same time a branch *3'3''* (fig. 11) operates the *regulator C*, which regulates the incoming feed water according to the discharge of the dirty water. This regulator (fig. 20) consists of a cylinder in which a float *P* guided vertically can move and work through a set of levers the balanced valve *d* admitting the make up water (figs. 11, 13 and 15). The water in the regulator is discharged by the main *V* (fig. 20) fitted with a cock *R* partly open, a similar main *V'* fitted with a cock *R'* allows air to escape or enter.

The same branch *3'3''* (fig. 11) carries the *automatic starting gear b* for the make up water circulating pumps (figs. 11, 12 and 15). The gear is like the regulator *C* described above. The float carries a spindle which makes or breaks the circuit of the circulating pumps P_c as soon as water flows in the blow down main, and stops the pumps P_c as soon as the boiler is empty.

The *heaters R* consist of a nest of brass tubes (figs. 16 and 21) : the dirty water fills the outer cylinder and the make up water passes through the tubes of each of the heaters R_1, R_2, R_3 and becomes heated. The *circulation of the make up water* is automatically assured by two groups of centrifugal pumps, one spare, driven by asynchronous squirrel cage type three-phase 3.5 H. P. motors. The starting of the motors is assured by an automatic « star-delta » contactor. To start these motors under load takes 4 to 5 times the normal current. The contactor puts the windings of the stator in star shape when starting up, and then in delta, which reduces the current absorbed to one-third when starting up. Figure 14 shews the contactors E_t in place.

The by-pass branches *mm* (fig. 11) enable any heater *R* to be cut out for repair or cleaning without stopping the plant. For cleaning purposes the part *A. B.* (fig. 21) of the heater can be removed from the back; the nest of tubes can be removed in the same way. The circulating pumps, like the other sets of pumps are underneath the two large reservoirs, so that they are self-charging.

After leaving the heaters, the dirty water runs through *4*, *5*, *6*, *7*, *8*, *9* to the *filter F.* (fig. 22) made up of two filters superposed on one another erected in parallel. The filtering material is gravel. The gravel can be cleaned at intervals by passing water through it in the opposite way, the gravel being raked over, whilst

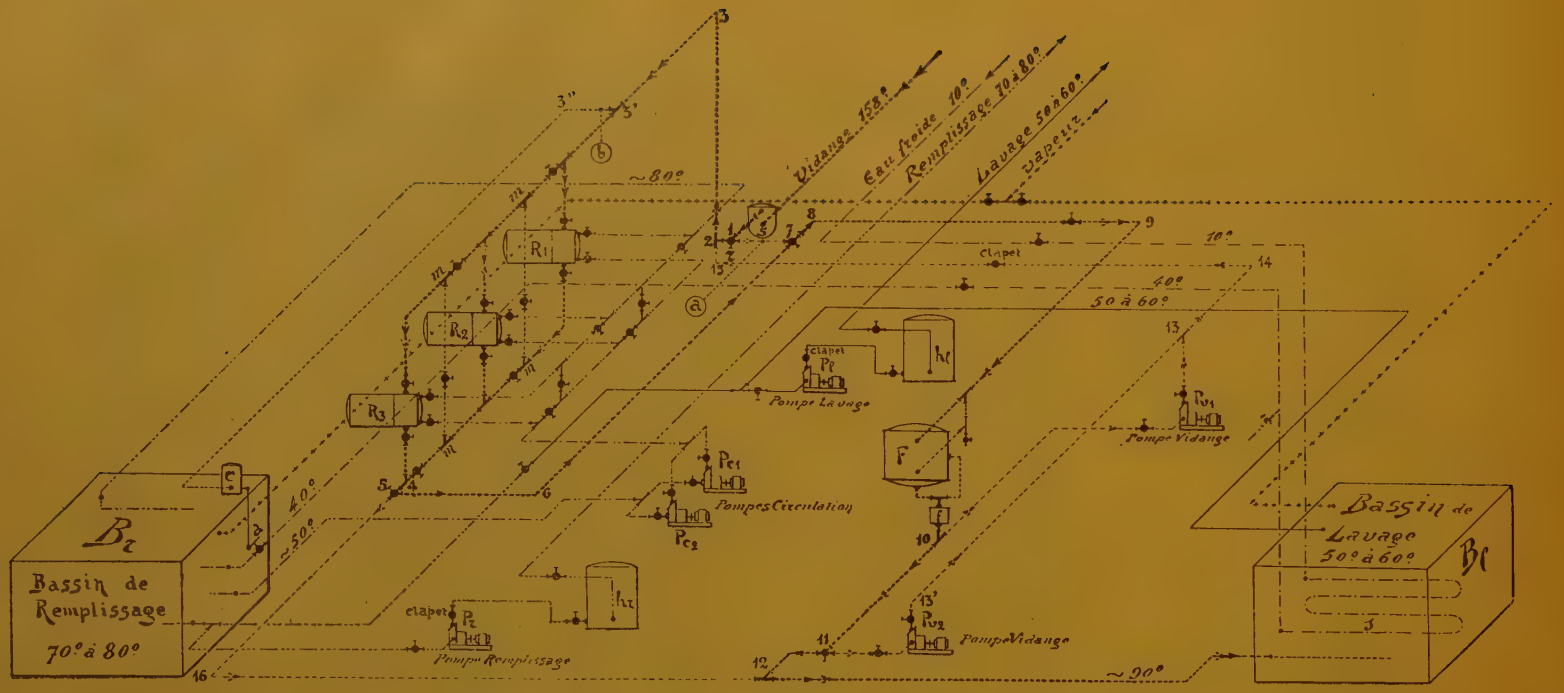


Fig. 11. — Lay out of heat recovery plant, Micheli system.

Discharge mains under pressure . . . . . S-1-2-3-R_1-R_2-R_3-4-5-6-7-8-9-F-f-10-11-12-Bl.

— — not under pressure . . . . S-1-7-8-9-F-f-10Pv_1 (or 11-Pv_2)-13 (or 13')-14-15-2-3-R_1-R_2-R_3-4-5 16-12 Bl.

Automatic starting up of the pumps, discharge . . . . . ⓐ

— — — — circulating . . . . . ⓑ

Explanation of French terms : Bassin de lavage = Washing out tank. — Bassin de remplissage = Filling up tank. — Clapet = Valve. — Eau froide = Cold water. — Lavage = Washing out. — Pompes circulation = Circulating pumps. — Pompe lavage = Washing out pump. — Pompe remplissage = Filling up pump. — Pompes vidange = Emptying out pump. — Remplissage = Filling up water. — Vapeur = Steam. — Vidange = Discharge.

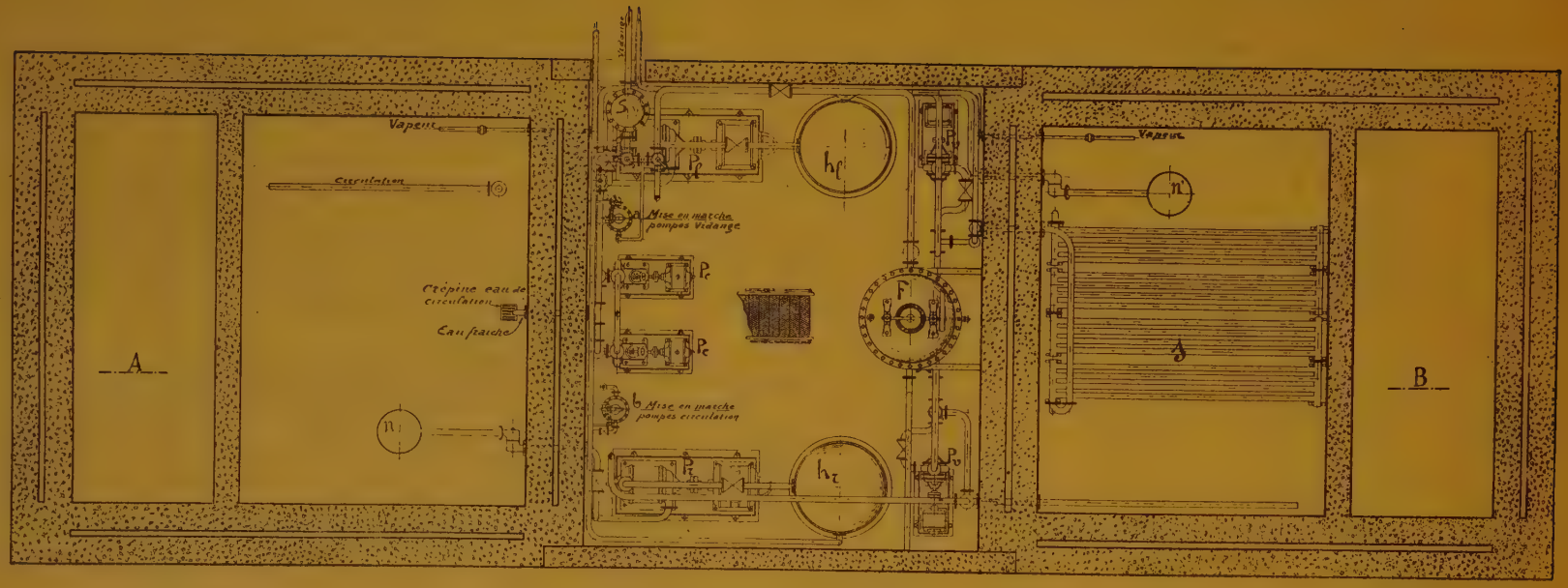


Fig. 12. — Micheli heat recovery plant. — Plan.

Explanation of French terms: Crépine eau de circulation = Circulating water strainer. — Eau fraiche = Fresh water. — Mise en marche = Starter. — Vapeur = Steam. — Vidange = Discharge.

it is being washed, by the rakes *h*, driven by the electric motor *m* of 3.5 H.P.

The dirty water passes through the small filter *f* (fig. 11) with wire netting to prevent the gravel from getting into the pumps. The water then goes to the reservoir B_l through the main *10*, *11* and *12*, B_l.

When discharging water from boilers not under pressure, the cock *r* is put in the proper position for the emptying out pumps P_{v_1} and P_{v_2}: the boiler water runs through the pipes *7*, *8* and *9* (fig. 11) to the filter *F* and to the emptying out pumps. At the same time a branch between the cocks 1 and 7 feeds *an automatic starter a*, with a float (figs. 11, 12 and 13) like those *b* and *c*; as soon as water flows in the main *1*, 7 the apparatus closes the starting switch of one or other of the pumps P_{v_1} or P_{v_2}. These are like the circulating pumps *Pc* — one spare — with an hourly capacity of 18 m³ (3 960 gallons) driven by an asynchronous squirrel cage type motor of 1.5 H.P., started up in the same way as the circulating pumps. The pump drives the dirty water through the mains *13* (or *13'*), *14*, *15*, *2*, *3*, and through the heaters R_1, R_2, R_3 into the reservoir B_l by the mains *5*, *16*, *12* (fig. 11).

b) *Heating the make up water.* — The initial temperature of the dirty water depends on the pressure at which the boiler is blown down. Under a pressure of about 5 kgr. per square centimetre (71 lb. per square inch) it is about 158° C. (316° F.). The washing out water cannot be hotter than 60° C. (140° F.) or the washers out have difficulty in handling the nozzles. The temperature of the filling up water should be as high as possible so that steam can be raised in the shortest time. At Schaerbeek under favourable conditions the temperature obtained is 70 to 80° C. (158 to 176° F.).

The tank B_r holds 42 m³ (9 240 gallons) of fresh feed water for the boilers at about 10° C. (50° F.). When blowing down, the valve *d* automatically admits to the tank B_r a quantity of water in proportion to the quantity given by the discharge main, which, before entering the tank, goes through the *coil S* (figs. 11, 12 and 13) immersed in the dirty water where it is heated to a temperature of about 40° C. (104° F.). When starting to blow down, one of the circulating pumps P_c starts automatically and pumps water from the tank B_r through the heaters *R*, so that the feed water has a temperature usually of 70 to 80° C. (158 to 176° F.) under favourable conditions.

c) *Washing out.* — The filtered dirty water is used to wash out the boilers. It is drawn from the tank B_l *through a floating nozzle n'* in the hottest part and pumped through the washing out main by the multi-cellular centrifugal pump P_l of 20 m³ (4 400 gallons) hourly capacity, driven by an asynchronous three-phase ring type motor of 15 H.P. (figs. 12 and 13).

A compressed air reservoir h_l, at 10 kgr. per square centimetre (142 lb. per square inch) pressure regulates the output of the pump and prevents water hammer blow in the main. The water in the tank is connected to *the hydro electric starter* of the pump motor, Micheli's system (figs. 18 and 23). The starter is set so that when the pressure in the tank exceeds 8 kgr. per square centimetre (114 lb. per square inch) the motor is stopped, and when it falls below 6 kgr. (85 lb.) the motor starts up again. The pipe between the tank and the starter includes a cooling coil *K* (figs. 14 and 18) so that the temperature of the water will not damage the joints of the starter. The sketch, figure 23,

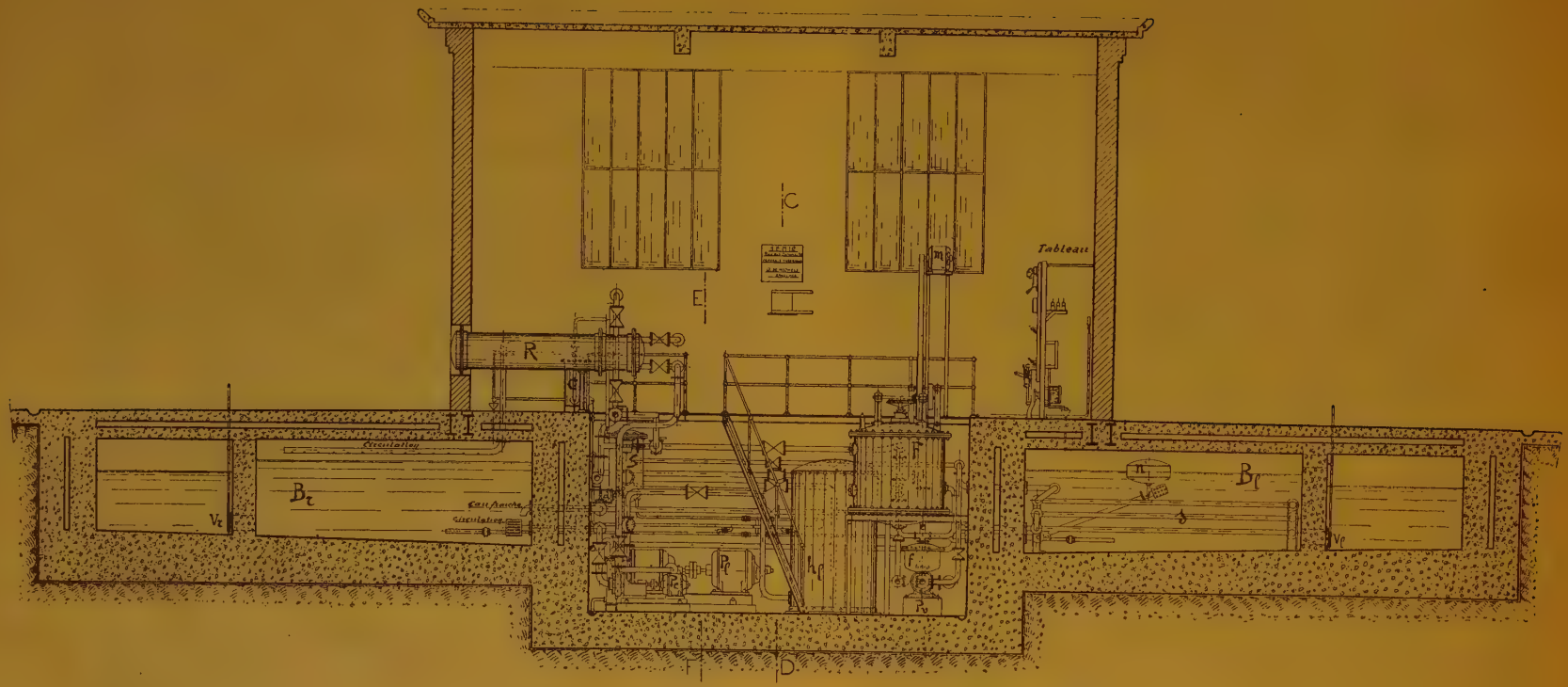


Fig. 13. — Micheli heat recovery plant. — Section AB.

Explanation of French terms : Tableau = Switchboard.

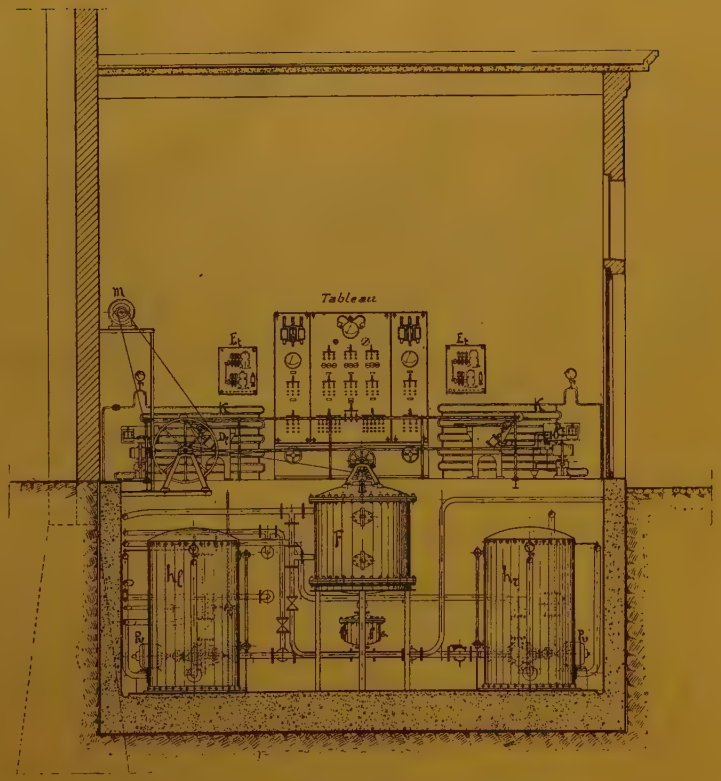


Fig. 14. — Micheli heat recovery plant.
Section CD.

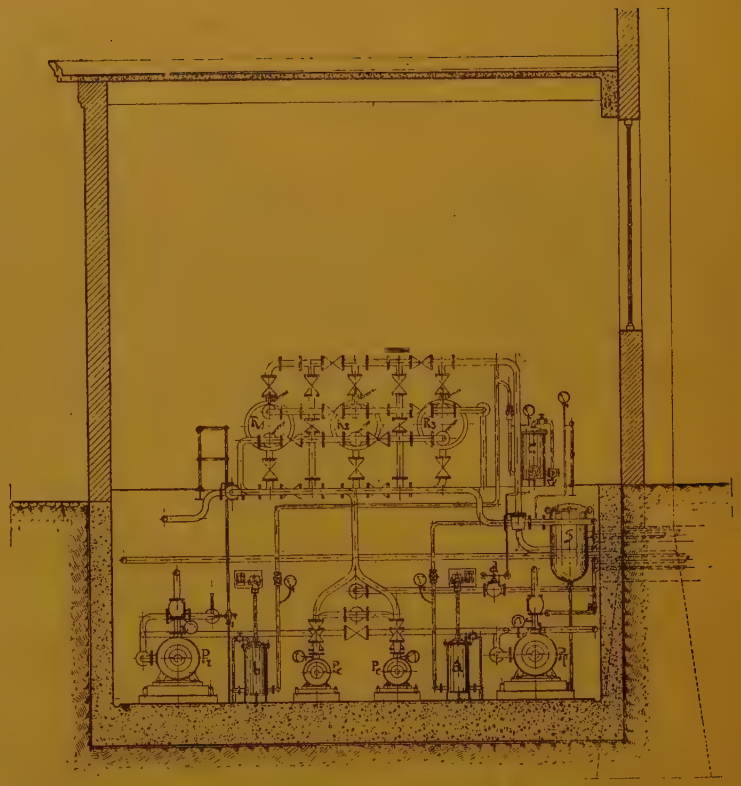


Fig. 15. — Micheli heat recovery plant.
Section EF.

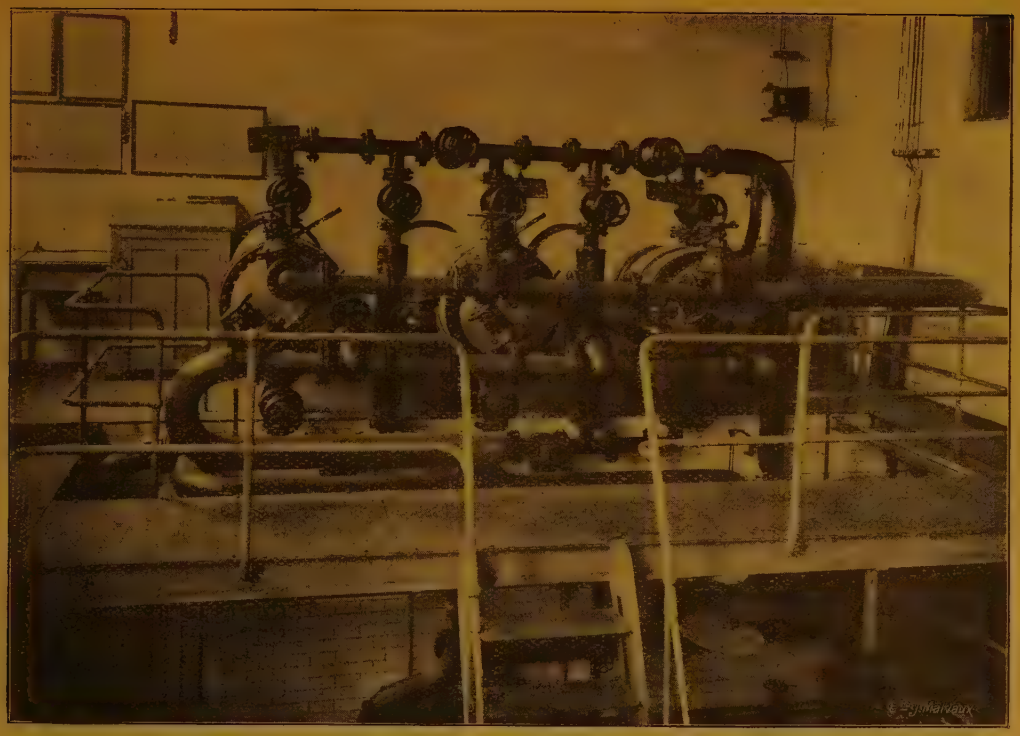


Fig. 16. — Micheli heat recovery plant. — Group of heaters.

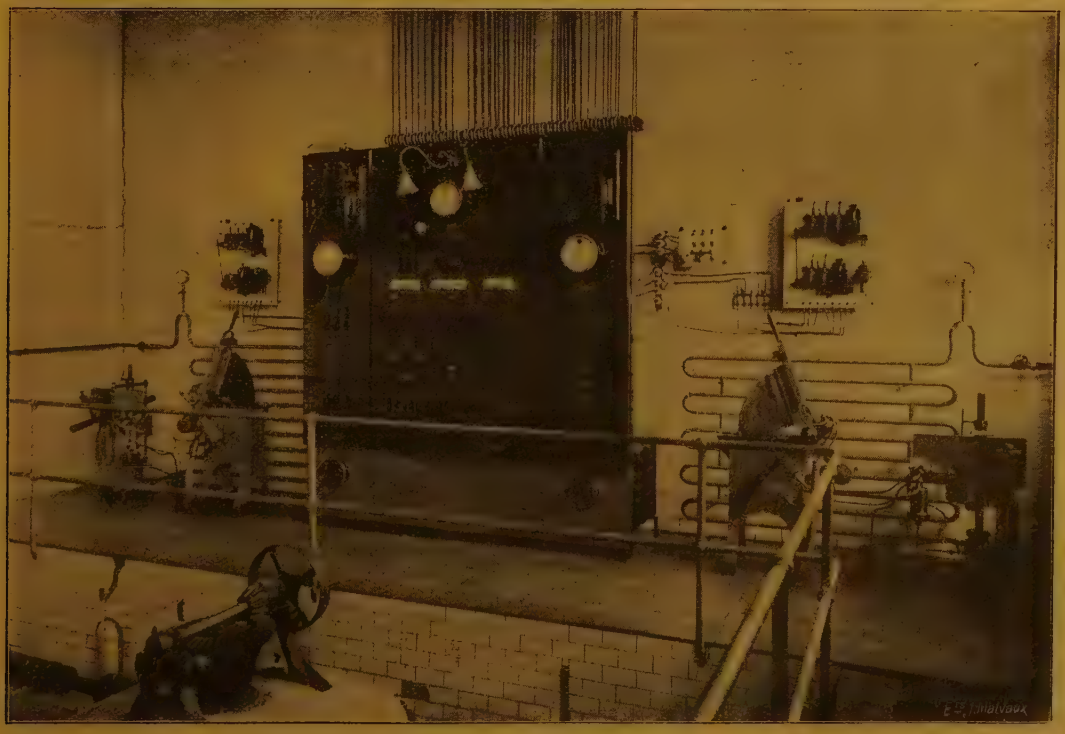


Fig. 18. — Micheli heat recovery plant. — Switchboard and automatic self starters.

Fig. 17. — Micheli heat recovery plant. — Feed water circulating pumps and washing out pump.

corresponds to the running position of the pump. As soon as the pressure in the tank h_l exceeds 8 kgr. per square centimetre (114 lb. per square inch) a counterbalance piston moving in the cylinder *C* lifts and reverses by a lever a tube of mercury. The movement of the mercury causes the tube to oscillate quickly and opens the switch *I* (stator circuits), and at the same time moves the valve of the distributor *D*. The water under pressure is driven into the top of the cylinder *E* whilst the lower end is opened to exhaust. The piston in the cylinder *E* lifts the plates of the liquid starter *F* through a rack and toothed wheel. When the pressure in the tank h_l falls below 6 kgr. per square centimetre (85 lb. per square inch) the operations are reversed, the switch *I* closes, the plates of the rheostat are lowered gradually so as to put into the windings of the rotor the required resistances for starting; at the end of the movement, corresponding to normal running of the motor, the resistances are short circuited. The motor can be started by hand if the automatic gear gets out of order.

In this way a pressure of 7 kgr. per square centimetre (100 lb. per square inch) is automatically kept up in the washing out main, which ensures a very powerful jet at the washing out nozzle.

d) *Filling up the boilers.* — The filling up is assured by an asynchronous motor multi-cellular centrifugal pump group P_r similar to that used for washing out. It forms a reserve unit for P_l and vice versa if one or other be under repair. The feed water in tank B_r is drawn out through a *floating suction* pipe *n*, a compressed air reservoir h_r regulating the pressure in the filling up water main. The pump is started by a hydro-electric gear like that described above.

The connection between the two tanks B_l and B_r enables any shortage of washing out water to be made up; moreover a live steam pipe from the boiler in the waste recovery plant can supply steam when needed to bring up the temperature in either of the tanks to the proper working temperature, should the dirty water be too cold.

B. — Capacity of the plant.

With the Schaerbeek plant 14 locomotives a day are washed out and refilled, that is, 7 or 8 of the most powerful goods engines, 4 or 5 six-coupled engines, and 1 or 2 eight-coupled shunting engines.

The plant was built to do the following work per eight hours day :

a) collect the dirty water from 20 locomotives at 5 kgr. per square centimetre (71 lb. per square inch) when blown down, each holding about 6 m³ (1 320 gallons) of water and 2.5 m³ (88 cubic feet) of steam. Under such conditions it takes 40 minutes to empty the boiler;

b) wash out the 20 boilers with hot water, taking about 40 minutes;

c) refill the 20 boilers with hot water in about 20 minutes each.

At Schaerbeek in ordinary use, 40 minutes to 1 h. 20 m. is taken to empty a boiler according to type and the pressure; washing out averages 1 hour due to the amount of scale from the bad water and 20 to 25 minutes is taken for refilling. Usually 2 locomotives are dealt with at a time. A number of boilers are blown down at night before the washing out staff come on duty.

C. — Operation and upkeep of the plant.

As the plant is fully automatic, in normal working no staff is required. The foreman washer-out sees from time to

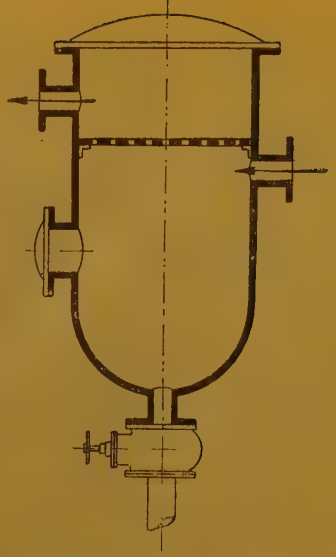


Fig. 19 — Mud collector-discharge water.

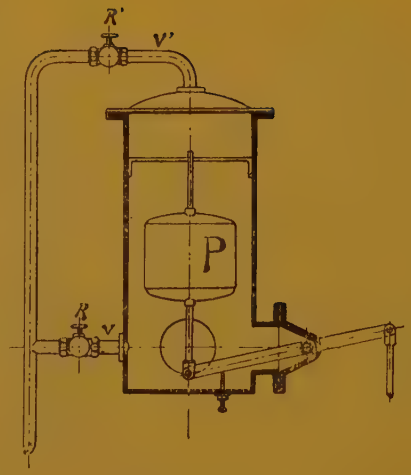


Fig. 20. — Making-up water regulator.

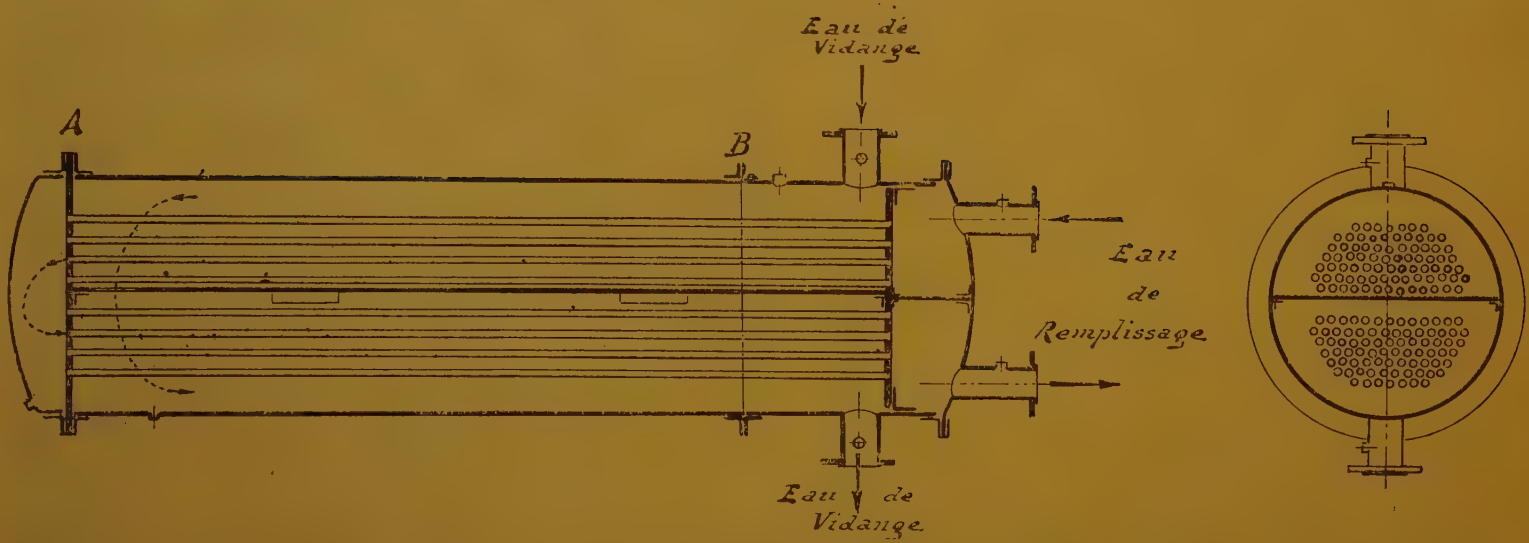


Fig. 21 — Feedwater heater.

Figs. 19 to 21. — Micheli heat recovery plant.

Explanation of French terms : Eau de remplissage = Filling up water. — Eau de vidange = Discharge water.

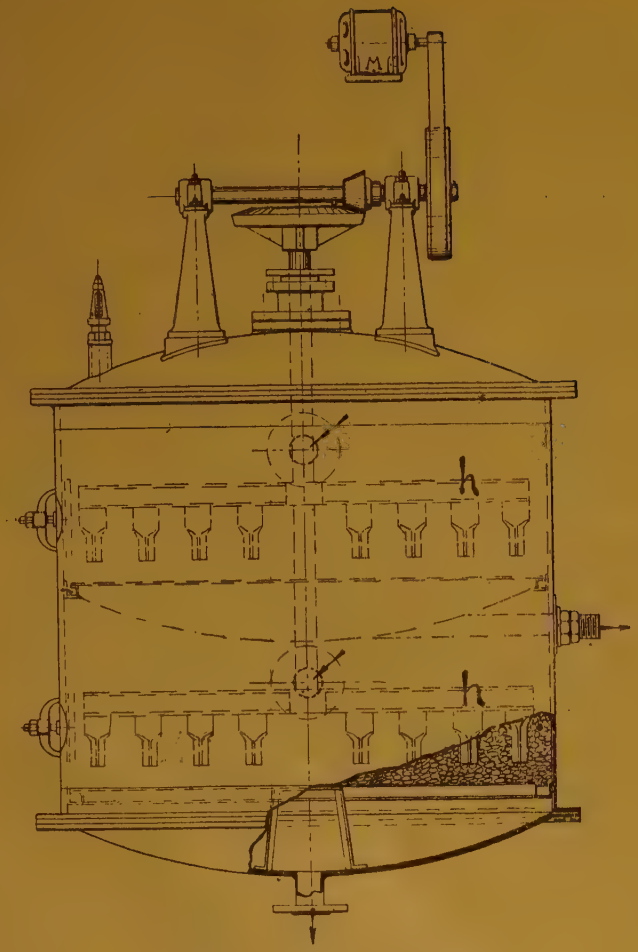


Fig. 22. — Discharge water filter.

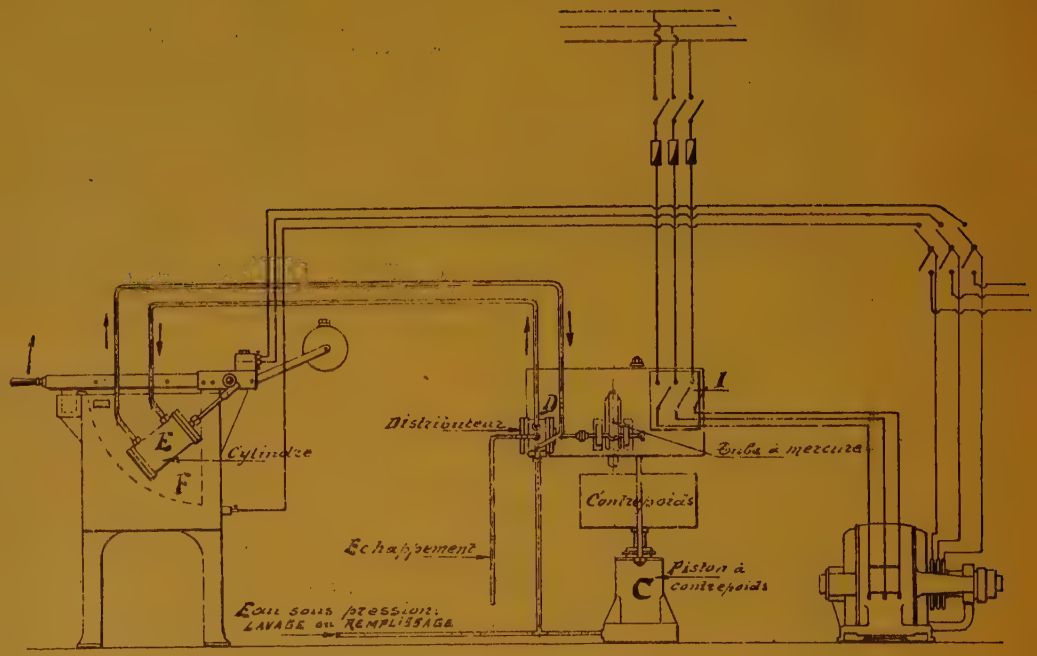


Fig. 23. — Hydro-electric starter.

Explanation of French terms : Cylindre = Cylinder. — Contrepoids = Counterbalance. — Distributeur = Distributor. — Eau sous pression = Water under pressure. — Echappement = Escape. — Lavage ou remplissage = Washing out or making up. — Piston à contrepoids = Counterbalanced piston. — Tube à mercure = Tube of mercury.

Figs. 22 and 23. — Micheli heat recovery plant.

time that everything is working correctly, the only thing he has to do being to set the two-way cocks when he has to empty a boiler not under pressure. Every six months the pumps and heaters are overhauled; each unit is inspected in turn so as not to interrupt the working of the plant. The filter is cleaned out weekly as described above. The washing out water tank is thoroughly cleaned out twice a year, and the filling up water tank, once a year. About two hours a day is allowed for cleaning out the building.

D. — Savings obtained.

The water emptied out at Schaerbeek is about 6 m³ (1 320 gallons) per engine and contains 800 000 calories (3 200 000 British thermal units). The mean washing out temperature is 55° C. (131° F.) and the filling up water is 67° C. (153° F.) in ordinary conditions. To get a clear idea of the facts, a daily table giving the pressures of boilers when emptied is given below, with the different temperatures.

From actual practical tests the *heat efficiency* of the plant (ratio of total calories in the washing out and filling up water to those in the water emptied out) is 80 to 85 %, so that about 660 000 calories (2 620 000 British thermal units) are recovered at each washing out. The return from the hot water washing out plant (stationary boiler, injectors or pumps) is about 50 %, so that the saving in fuel obtained with the Micheli plant for each washing out is $\frac{660\,000}{7\,500 \times 0.50}$ = 0.176 t. of the value of 180 fr. × 0.176 = 31.68 fr. In addition 7 m³ (1 540 gallons) of water (including the feed water of the stationary boilers) is saved each washing out, costing 0.45 fr. × 7 = 3.15 fr. The saving of fuel and water for each washing out and refilling can be taken at 35 fr. which means $35 \times 14 \times 300 = 147\,000$ fr. a year. The cost of upkeep, power, and interest in capital, are higher than for the usual type.

The actual net saving given by the central hot water plant at Schaerbeek can be obtained from the following figures, all upkeep, interest, and depreciation charges being included. The figures are for six months for the whole of the plants on the system :

The average cost of washing out and refilling a boiler with hot water at Schaerbeek is 70.47 — 48.15 = 22.32 fr. less than the average cost of the same work at the other plants on the system. The net saving obtained from the Schaerbeek plant is therefore $2 \times 2\,070 \times 22.32$ fr. = 92 405 fr. a year. The real saving is greater as the feed water at Schaerbeek is taken from the local supply and is very dear, and, on the other hand, the plant gives much higher temperatures than any of the others.

The principal savings are due to :

1. Saving in labour as the work can be done with fewer washers out, and a fireman for the stationary boiler is not required. The saving under this head is $2 \times 2\,070 \times 4.05 = 16\,767$ fr.

2. Saving of fuel. The saving under this head is shewn by the accounts to be about 110 000 fr. a year. Whereas in the ordinary plants the temperature of the washing out and filling up water is not above 50° C. (122° F.), at Schaerbeek it is usually $\frac{55 + 67}{2} = 61°$ C (142° F.) If the mean feed water temperature be taken as 10° C. (50° F.), the saving in fuel would be $110\,000 \times \frac{51}{40} = 140\,000$ fr. or

NUMBER OF THE LOCOMOTIVE.	TYPE OF LOCOMOTIVE.	Pressure when emptied out.		Temperature of washing out water		Temperature of filling up water.	
		Kgr. per cm².	Lb. per sq. in.	C.	F.	C.	F.
1924	0-6-0 goods.	2	28	55	131	70	158
4894	0-8-0 shunting.	5	71	57	135	72	162
4453	2-10-0 goods.	6	85	50	122	70	158
5079	2-8-0 —	4	57	55	131	80	176
4492	2-10-0 —	4	57	60	140	79	174
5031	2-8-0 —	2	28	60	140	75	167
8177	0-8-0 —	5	71	50	122	63	145
1862	0-6-0 —	5	71	53	127	62	144
8288	0 8-0 —	6	85	52	126	72	162
4306	0-6-0 —	6	85	52	126	51	124
3151	0-6-0 —	6	85	52	126	51	124
2755	0-6-0 —	3	43	51	124	51	124

EXPENDITURE UNDER HEADINGS		All plants on system excluding Schaerbeek.	Schaerbeek central hot water plant.
Total cost of labour, washers out and firemen . .	During half year considered.	1 401 129 fr.	55 416 fr.
Total cost of fuel.		1 207 875 fr.	Nil.
Total cost of water		174 535 fr.	7 267 fr.
Total cost of repairs		127 898 fr.	10 157 fr.
Cost of power.		20 560 fr.	6 532 fr.
General charges		157 390 fr.	3 015 fr.
Interests and depreciations		114 250 fr.	17 300 fr.
Grand total of expenditure		3 203 637 fr.	99 687 fr.
Total number of boilers washed out and filled . .		45 461	2 070
Cost of labour (washers out and firemen)	Per each washing out and filling up.	30.82 fr.	26.77 fr.
Cost of fuel		26.57 fr.	Nil.
Cost of water.		3.84 fr.	3.53 fr.
Cost of upkeep		2.82 fr.	4.90 fr.
Cos ofpower.		0.45 fr.	3.15 fr.
General charges		3.46 fr.	1.45 fr.
Interest and depreciation		2.51 fr.	8.35 fr.
Total cost		70.47 fr.	48.15 fr.

a further gain of 30 000 fr. These figures substantiate the approximation made above.

3. Saving in washing out water and feed water of stationary boilers. The saving shewn in the statistics is small because the average price of water at the other plants is only 0.22 fr. per cubic metre, whereas at Schaerbeek it is 0.45 fr. The true saving on water per wash out and re-fill was calculated above and amounts to 3.60 fr., which means an increased saving of $3.60 - (3.84 - 3.53) = 3.29$ fr. or $2 \times 2\,070 \times 3.29$ fr. $= 13\,620$ fr. a year above that shewn by the statistics.

Actually the *net annual saving* of the Schaerbeek plant, all upkeep and capital charges on the first cost being taken into account amounts to $92\,405 + 30\,000 + 13\,620 = 136\,025$ fr. The plant will pay for itself in less than three years. Amongst other advantages the washing out is quicker and better owing to the high pressure at the nozzle, so that the plant fills an important factor in reducing the time the engines are stopped.

IV. — Cotton waste recovery plant.

The plant (fig. 24) includes :

1. A Galloway boiler, 11 m² (118 square feet) heating surface, 10 kgr. per cm² (142 lb. per square inch) pressure.
2. Store for dirty locomotive waste sent to Schaerbeek from the various depots.
3. Recovery plant.
4. Store for recovered waste.

The machinery was supplied by the I. W. E. L. (Industrial Waste Eliminators Limited).

The waste first of all passes through a *turbine centrifugal extractor and separator* (fig. 25) which has a rim with blades *A* forming the driving turbine fastened to the perforated steel cage *B* which holds the loose metal container with perforated sides, in which the waste to be treated is put. Steam is introduced by the pipe *C* and, after passing through and driving the turbine, it flows into the cover *D* through the waste, and then out by the exhaust *E*. The oily matter in the waste under the action of the exhaust steam and centrifugal force is forced into the outer casing *F*, through the perforations in the cage *B*, and flows out through the opening *G* into a suitable receiver.

The container will take 75 kgr. (165 lb.) of dirty waste, which takes 40 minutes to clean, and with its contents is removed from the extractor by a light wall jib crane.

The waste then goes through a reversible *mechanical washing machine*, in which it is washed with soap and soda, taking about 25 minutes. The waste is given one rinsing in the washer by replacing the washing water by clean water. The rinsing is continued in an ordinary centrifugal *drier* until the outlet water is clean; the machine then dries the waste as much as possible. The waste is then laid out on galvanised shelves in a *drying cupboard*. The shelves are carried on metallic moveable stands which can be removed from the drier as required. The cupboard is steam heated by ribbed tubing; in the upper part there is a belt driven fan to circulate the hot air, and a ventilating pipe for removing the moist air.

The mixture of oil and water removed from the waste is emptied into two *settling tanks* (fig. 26) of 900 litres (198 gallons) capacity, heated by a steam coil. The mixture enters through a funnel *A* at the bottom, and the oil which rises is removed by a pipe with a copper float *D* coupled to an articulated joint with a cock *C* at the other end. The deposit and

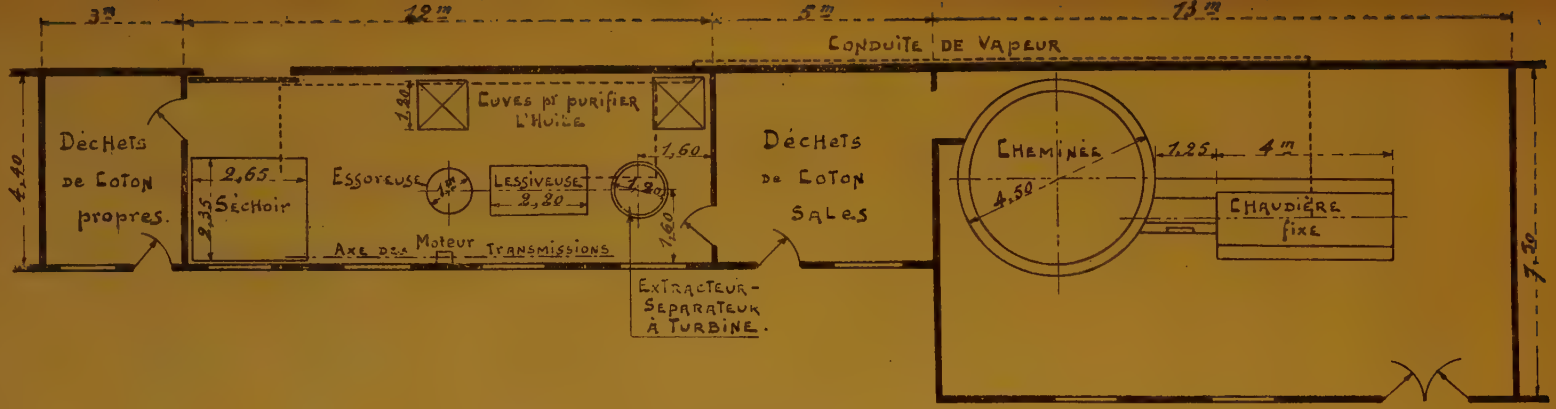


Fig. 24. — Cotton waste recovery plant. — Plan.

Explanation of French terms : Axe des transmissions = Centre line of shafting. — Chaudière fixe = Stationary boiler. — Cheminée = Chimney. — Conduite de vapeur = Steam pipe. — Cuves pour purifier l'huile = Tank to clean the oil. — Déchets de coton propres = Clean waste. — Déchets de coton sales = Dirty cotton waste. — Essoreuse = Drier. — Extracteur-séparateur à turbine = Turbine extractor-separator. — Lessiveuse = Washer. = Moteur = Motor. — Séchoir = Drier.

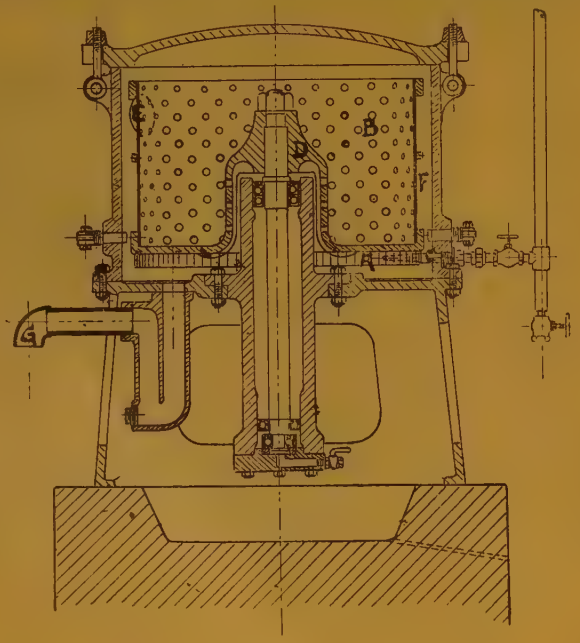


Fig. 25. — Turbine extractor-separator.

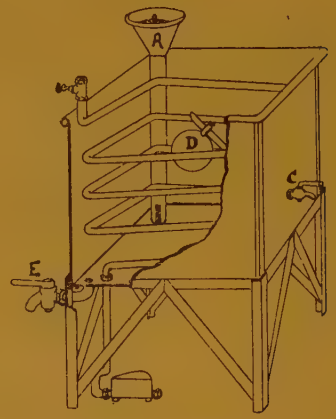


Fig. 26. — Settling tank.

the water are discharged through a large valve *E*.

The plant is double shifted and deals with about 500 kgr.(1 100 lb.) of dirty waste per shift of 8 hours. The total cost per kilogram of dirty waste is 0.60 fr. This figure includes labour (0.20 fr.), fuel, water and washing powder (0.14 fr.), transport of dirty waste (0.12 fr.), power (0.07 fr.), interest and depreciation of plant (0.07 fr.).

The recovered waste is valued at 3/4 of new, and is good enough for cleaning locomotives, although it is rather less absorbent than new waste. A kilogram of waste treated yields an average of 0.5 kgr. of recovered waste worth 1.45 fr., and 120 gr. of oil worth 0.15 fr. The net gain per kilogram of dirty waste treated is therefore 1 fr.; the annual saving made from the plant which cost 36 000 fr. to install is about 300.000 fr.

V. — Central mixing plant and stocking of slack coal.

A. — General method of operating the plant.

The choice of locomotive coal for the Belgian Railways primarily depends on the output of the collieries of the country. The Company is obliged to purchase coals of very varying qualities, such as semi-bituminous coals with 13 to 18 % of volatile matter, semi-anthracite coal with 8 to 13 % volatile, which are not suitable for locomotive purposes, and have to be improved by mixture with bituminous coal (20 to 32 % volatile) so as to get semi-bituminous coals with about 18 % volatile. For each of these three qualities of coal there is quite a wide difference in the ash content, even as much as 12 %. There are therefore low ash semi-bituminous coals (up to 10 % of ash), semi-bituminous of average ash content (10 to 14 % ash), semi-bituminous of high ash content (14 to 20 % ash). The coal also varies in the fusibility of the ash and in coking qualities.

The mixing plant has 4 storage hoppers for holding the coal before mixing, although more than four qualities of fuel are supplied, as will be seen later. It is therefore impracticable to classify them into 4 types, one per storage hopper, particularly as one of these is usually kept in reserve. In this way the three hoppers are usually allotted to bituminous coal (*G*), semi-bituminous (*D*) and hard (*M*), which three qualities are used in comparable quantities in the mixture.

In each of the three kinds there is a wide difference in the volatile content. It is therefore necessary to make a preliminary mixture for each category before filling up the hoppers. The coals are therefore divided into bituminous with high volatile content (*GF*), bituminous with low volatile (*GA*), long flame semi-bituminous (*DF*) or short flame semi-bituminous (*DA*), long flame semi-anthracite (*MF*) and short flame semi-anthracite (*MA*), so that as regards the volatile content there are six qualities.

The second important component to be covered in the mixture is the ash content. Here again the fuel has to be mixed before it is put in the hoppers. The six above qualities are divided into three further classes according as « clean » (*p*), moderately clean (*m*), and dirty (*s*) are in question. The rake of wagons for the mixing plant is shunted on to the fan of six sidings set aside as follows :

No. 1 road : good semi-bituminous coals (*DF*);

No. 2 road : poor semi-bituminous coals (*DA*);

No. 3 road : good hard coal (*MF*);

No. 4 road : poor hard coal (*MA*);

No. 5 road : good bituminous coal (*GF*);

No. 6 road : poor bituminous coal (*GA*).

On each road, wagons of average ash content are first put in place, then wagons of clean and dirty coal in turn.

When wanted for tipping, the wagons are taken in rakes of 12, two from each track. A rake will then consist of 4 wagons of each of the three main qualities : two « good » of average ash content (or one « clean » « good » and one « good » « dirty » and two « poor » of average or of different ash contents. The make up of the rake is also checked and, if necessary, modified to take into account the fusibility of the ash. Each group of 4 wagons being for one hopper, the coals are mixed in the mass in the tippler pit, and again when falling into the hopper itself. Each hopper of unmixed coal contains an average quality of coal from first mixture of coals more or less rich in volatile matter, and more or less clean.

A second and better mixture is obtained on the conveyor belts by means of a measuring device which adds the quantity of other coal required to get the mixture wanted. The thoroughness of the mixture is completed by the subsequent handling of the fuel.

The *supply of wagons of coal* is regulated by the central control which uses a table giving the composition of the small coal from the different pits obtained from analyses made in the regional laboratories of the Inspection Service. The table is kept up to date monthly in accordance with the latest analyses. The shunter marks the numbers of the tracks into which the wagons are to go in accordance with the table; for example, a wagon of the category *DE p* is marked *1, p* so that the shunters have only to separate the wagons marked *p* and *s*.

The central service is also given particulars of the fusibility of the ash and of the agglutinative power, and arranges to send a suitable selection of wagons to the mixing plant. The rakes are checked to see this is done.

The mixing of the coal is supervised systematically at the *fuel tests laboratory* at Schaerbeek near the plant itself, in which frequent analyses are quickly made to check the quality obtained and to alter the composition as necessary. Check analyses are also made frequently. The laboratory is fitted out to determine the moisture, ash and volatile contents, temperature of fusing of ash, and agglutinative power. The mixed coal has 18 % volatile matter and 13 % ash content.

B. — Description of the plant and method of operating the equipment.

1. *Mixing plant.*

a) *Unloading wagons.* — The plant as originally designed only included one side tipping tippler (1), selected because a large proportion of the wagons on the Belgian railways (about 40 %) have not got end doors, many have only one side door. The side tippler can handle 120 tons an hour when the wagons have two side doors and the coal is dry, but not when the coal is wet or the wagons have only a single door. It was consequently decided, soon after the plant had been in use, to put in an end tippler to deal with end door wagons. The tipplers made it possible to handle 120 tons per hour for which the rest of the plant is designed (figs. 27 to 34).

Side tippler, Kainscop type, at 45° (fig. 35) consists of a metal platform *a* on three sectors *b* of special contour carried on the horizontal runways *C*. The

sectors have recesses *e* corresponding to the teeth *d* on the runways. The wagon to be emptied is supported on its side, when being tipped, on a cross bearer *t* supported at the ends by the rollers of the brackets *s*, and can be adjusted at right angles to the track. It is driven by a worm *v* carried by the uprights *m*. The table is tipped by the two rods *l* carried on the discs *p* driven by an electric motor *m* and gearing. The driving discs *p* rotate continuously. When the wagon has been emptied the motor clutch is let in, and the motor running in the same direction as during tipping the rods pass the dead centre and the table returns to its horizontal position. The profile of the sectors is arranged so that the centre of gravity of the wagon is displaced horizontally. The motor has therefore only to overcome passive resistances. It is 7.5 H. P. and also drives an electric capstan *C* for pulling the wagons on to the table. The capstan can only be used when the table is in the horizontal position.

End tippler, Kainscop system (fig. 36) operates in the same way as the side tippler. When being tipped the buffers bear on an *end stay t* jointed at one of its supports. After the tippler has been returned to its original position, the cross stay can be removed so that the wagon can be moved on and not have to come back over the same line. The stay is locked in the horizontal position for safety. A capstan is also fitted as before. The tipping angle is also 45°; the driving motor is 10 H. P.

The tipping of dry coal is attended by a cloud of dust; to stop it, a shelter 15 m. (50 feet) long has been erected over the tippler (fig. 30). This shelter, which is closed in as much as possible on all sides, has the two ends openings to the rolling stock gauge. It has reduced the action of the wind on the dust formed when the truck is turned over. A hood in sheet steel *H* (fig. 30) forms the suction chamber for the dust. The top of it forms a foot-path for the men emptying the wagons. The dust is exhausted by a Sturtevant *f* an *V*, driven by a 7.5 H. P. electric motor of 3 m³ (106 cubic feet) per second with a reduction in pressure of 10 to 12 mm. (0.4 to 0.5 inch) at the openings into the hood. The dust is forced into a centrifugal separator *S* of the « cyclone » type where it is collected and then sent into one of the hoppers of unmixed coal.

b) *Loading unmixed coal into the hoppers.* — The coal from the side tippler falls into a hopper-shaped pit, of 50 tons capacity, covered by a grating to prevent too large lumps or other foreign matter, such as pit timber, etc., getting into it, which might damage the gear. The hopper has at the bottom two openings under each of which a *reciprocating charging device* (fig. 37) assures the regular feeding of the bucket conveyors (**2** and **3**). This charger consists of a box-shaped channel on four rollers, into which the end of the hopper discharges, and is driven by rod and eccentric. The eccentric is keyed to a shaft driven by the bottom shaft of the elevator by a Galle chain, so that the output of the two plants shall be the same. A vane *v* regulates the depth of coal the charger loads into the buckets during the return stroke.

The chains of the *bucket elevators* (fig. 38) are made up of flat side links *a* of semi-hard steel, alternatively with double links *b* made of rather thinner plate. These links carry the ironwork of the buckets. They are articulated about the pins *p* on the rollers in cast iron *g* attached to the pins and greased at the ends by screwed in Stauffer greasers.

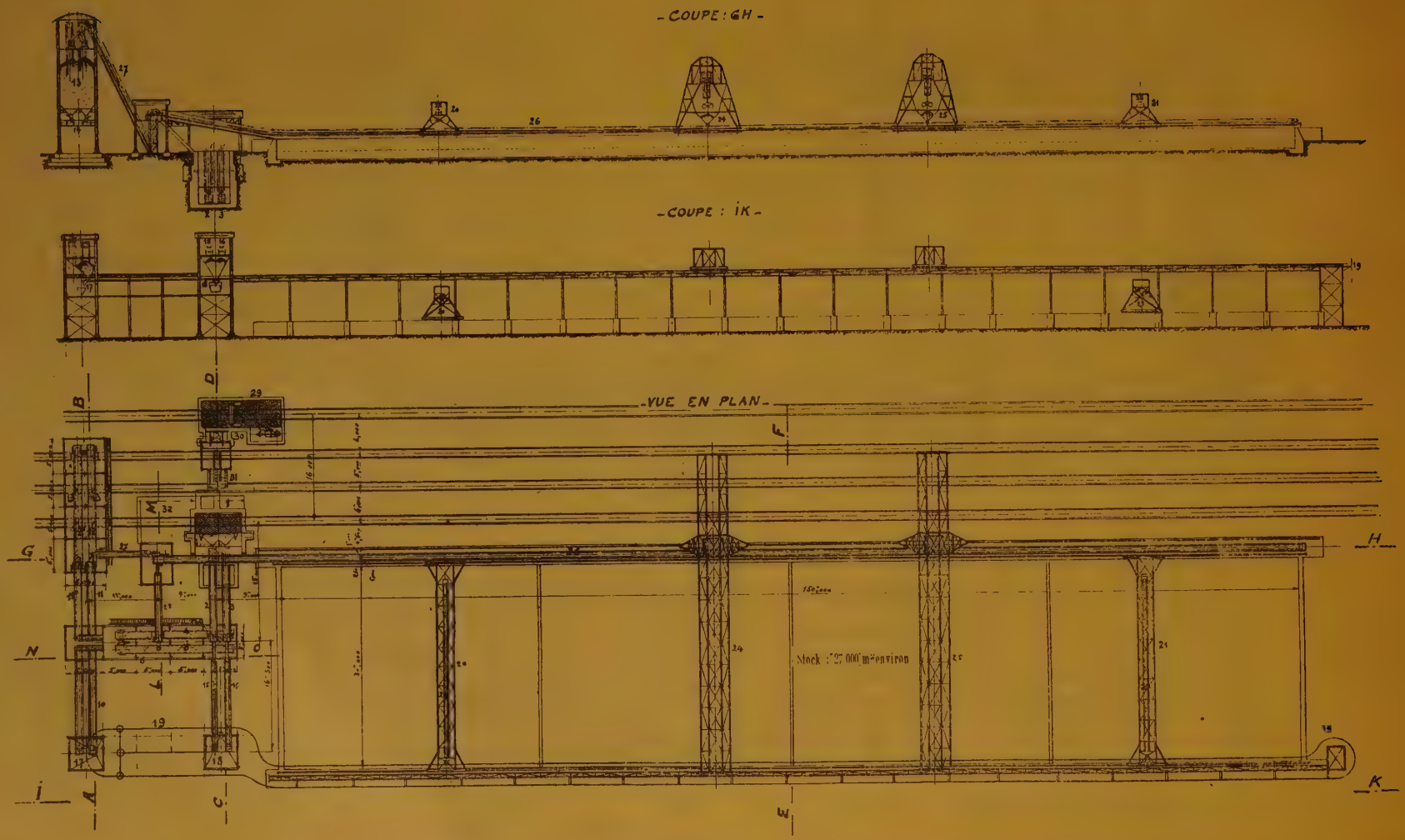


Fig. 27. — Schaerbeek depot. — General arrangement of the central coal mixing plant and storage.

Explanation of French terms : Coupe = Section. — Vue en plan = Plan view. = Environ = About.

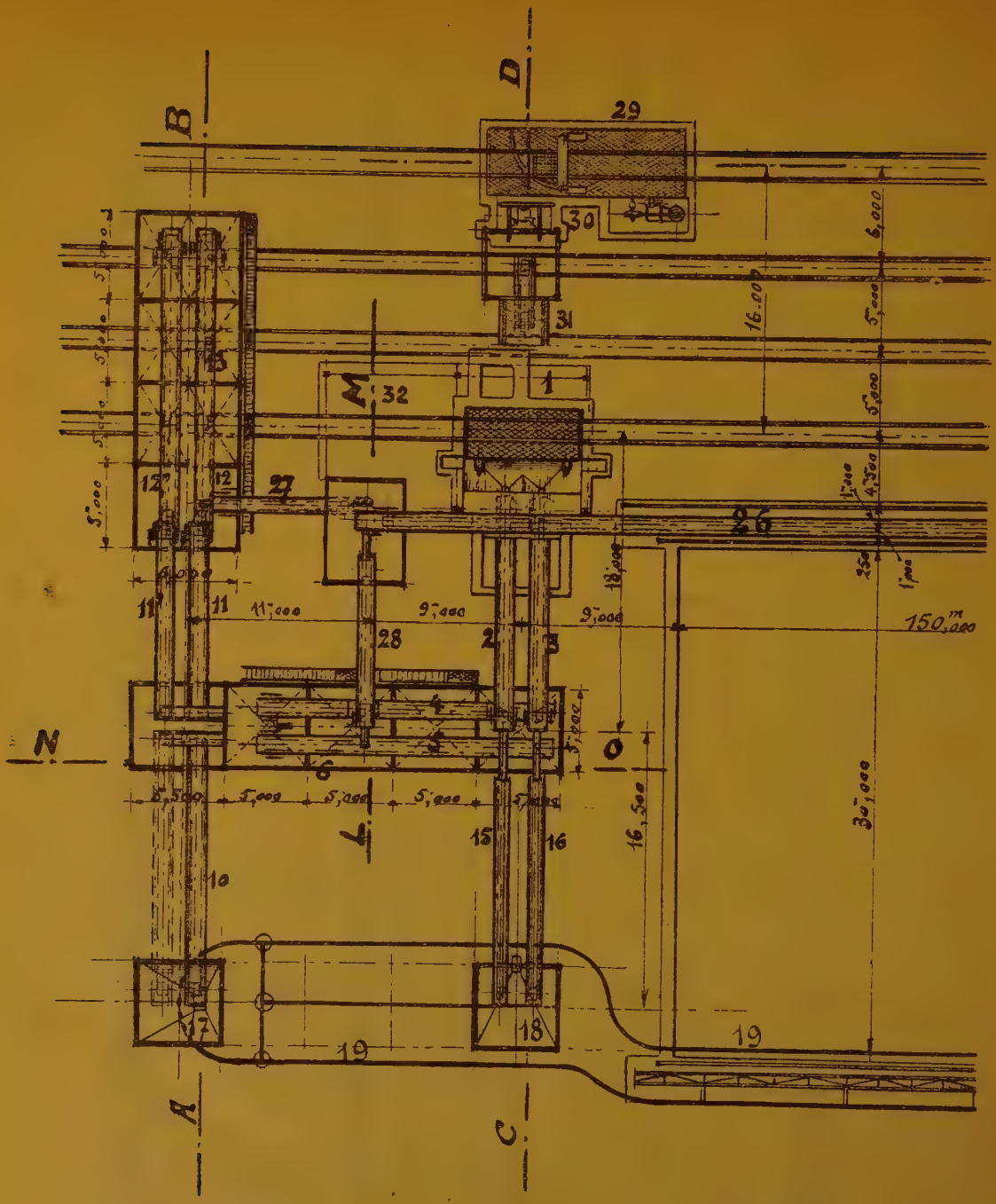


Fig. 28. — Plan of the mixing plant itself.

Explanations : figures 27 to 33.

1 = Side wagon tippler. — 2-3 = Bucket conveyor for unmixed coal. — 4-5 = Rake conveyor. — 6 = Mixing hoppers. — 7 = Mixing tables. — 8-9 = Belt conveyors. — 10-11 = Bucket conveyor for mixed coal. — 12-12' = Rake conveyor. — 13 = Coaling towers. — 14 = Coaling valves. — 15-16 = Metal conveyors for unmixed coal. — 17-18 = Hoppers feeding the monorail. — 19 = Electric monorail with self emptying tubs. — 20-21 = Travelling cranes for putting down coal for stock. — 22-23 = Belt conveyors with cradles. — 24-25 = Cranes for picking up stock coal with grabs. — 26 = Metal conveyor for dealing with picked up coal. — 27-28 = Bucket conveyor for coal from stock. — 29 = Wagon end tippler. — 30 = Bucket conveyor for unmixed coal of 120 tons an hour capacity. — 31 = Robins belt conveyor of 120 tons an hour capacity. — 32 = Shelter over side tippler. — 33 = Dust extractor.

These rollers roll on the runways *r* carried on the elevator frame *B*. The frame is trough shaped with two angles *c* to take the rollers.

The teeth on the rims of the drums drive the chains by the double links. The bottom drum shaft is carried in adjustable bearings. Each bucket conveyor can handle 60 tons an hour. The buckets hold 35 litres (1.2 cubic feet). The speed of the chain is 360 mm. (1.2 feet per second) and is driven by a 15 H.P. motor.

In the case of the end tipping tippler, the hopper has only one charger feeding one *bucket elevator* (**30**) of 120 tons an hour capacity similar to those described above, driven by a 15 H.P. motor, and shewn in figure 30. This conveyor discharges on to a rubber belt conveyor (**31**) of the Robins type 800 mm. (31 1/2 inches) wide capable of 120 tons capacity an hour. Its speed is 1.800 m. (6 feet per second), its length is 32 m. (105 feet), and the motor is 10 H.P. The belt is enclosed in a metal framed trunking with floor and sides in wood, covered with corrugated sheeting, and feeds the coal through discharge troughs to the same transporters as the two elevators for the side tippler.

The two *rake conveyors* (**4** and **5**) above the four storage silos, or the two *plate conveyors* (**15** and **16**) supply the loading hopper of the storage yard monorail according as the coal has to be mixed at once or sent to the store yard.

Each *rake conveyor* (**4** and **5**) has an output of 60 tons an hour. Each of them consists of two endless parallel chains (fig. 40) carrying at regular intervals pieces of board which push before them the coal in a channel *a*. The chains are like those of the bucket elevators, but are not fitted with rollers; they slide on wearing plates *p* carried on angles attached to the sides of the frame. The frame is shaped like a long rectangular box, the bottom of which at the level of the hoppers has an opening which can be closed by a sliding plate. The conveyor is driven by a drum with a 10 H.P. motor. The coal brought up by the bucket conveyor or by the Robins belt is discharged into the end of the box shaped frame, and then is taken by the rakes until it falls into one or other of the main hoppers as arranged. The chains pass over a return drum with adjustable bearings. The return side is in the upper part of the frame. The speed of the rake conveyor is 0.400 m. (16 inches) a second. It should be noted that the rake conveyor can deliver material in both directions without it being necessary to reverse the chain. It is only necessary to make use of the return side by enclosing it in a hollow frame. The rake conveyor (**4**) has the one particular feature : It is necessary to be able to feed any one hopper with coal brought up by the second bucket conveyor (**28**) with its rake off plate about mid-length; it will meet the requirements if the coal is raked off from the top or bottom according to the desired direction.

c) *Mixing of coal.* — The building set aside for mixing coal (**6**) contains 4 hoppers, each of 120 tons capacity. The first is for semi-anthracite coal, the next for the bituminous, and the last two for two qualities of semi-bituminous coals. The hoppers are made up of a metal framework filled in with bricks; the bottom of conical form is in steel plate 6 mm. (1/4 inch) thick with stiffening angles.

Under each hopper a *measuring table* or *turntable* with adjustable output is provided (figs. 39 and 41). The table consists of a circular table **1**, 1.40 m. (55 inches) diameter turning about a vertical driving axis *2*. The lower part of the bottom of the hopper *3* is fitted

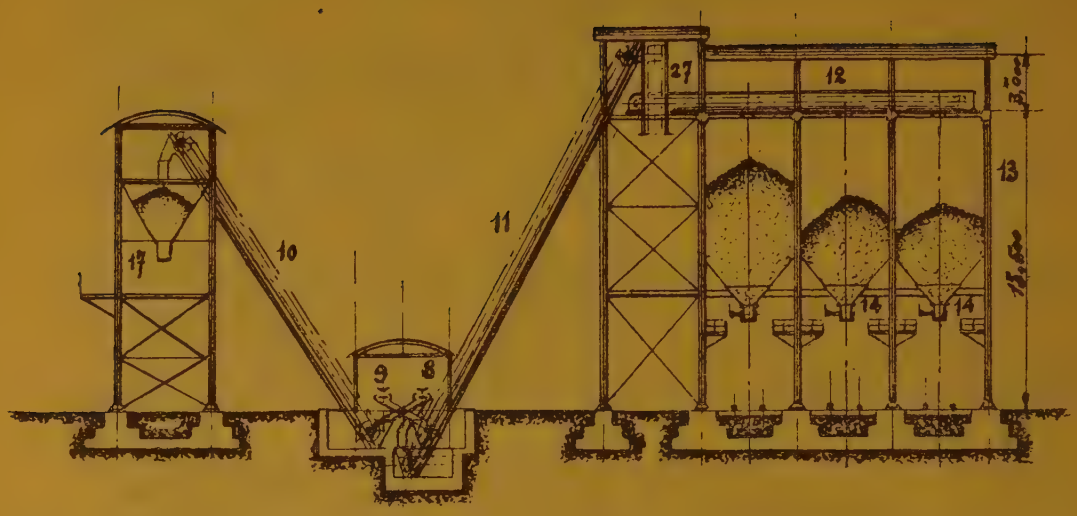


Fig. 29. — Mixing plant. — Section on AB.

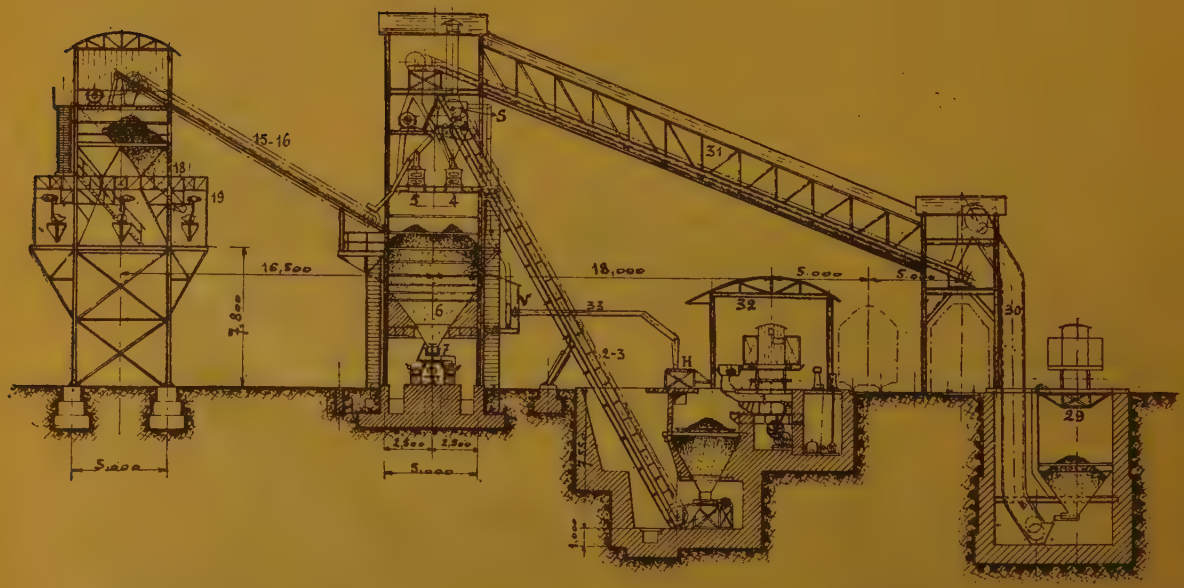


Fig. 30. — Mixing plant. — Section on CD.

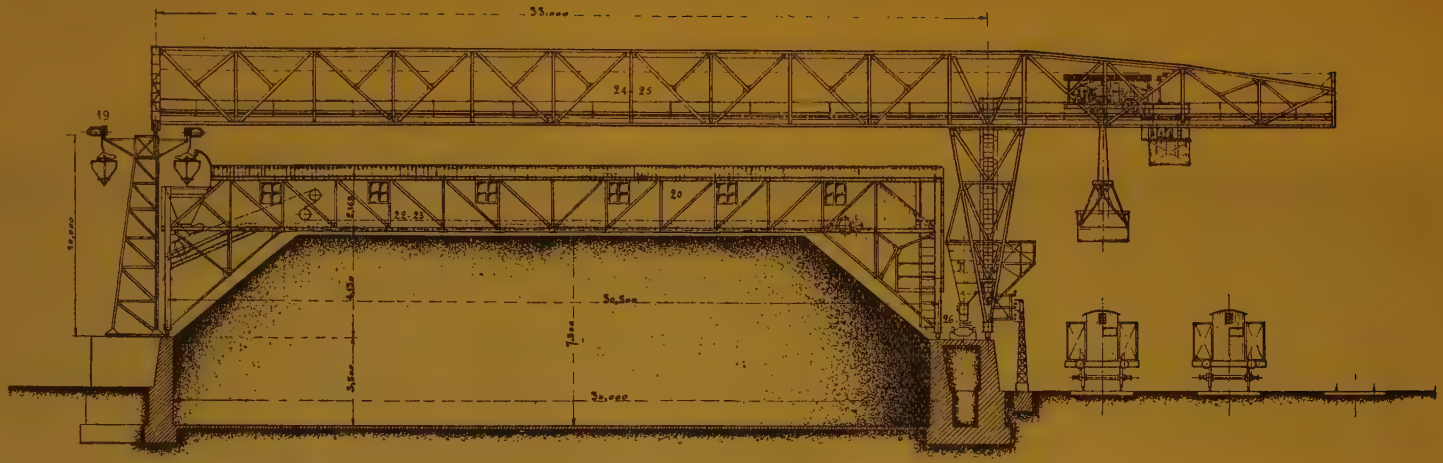


Fig. 31. — Mixing plant. — Section on EF.

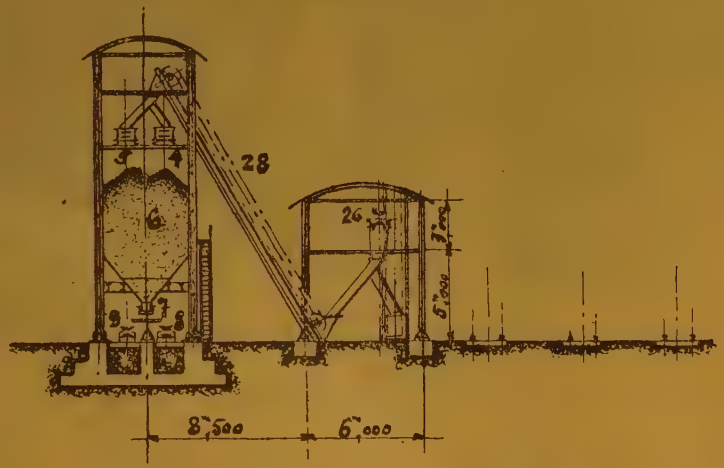


Fig. 32. — Mixing plant. — Section on LM.

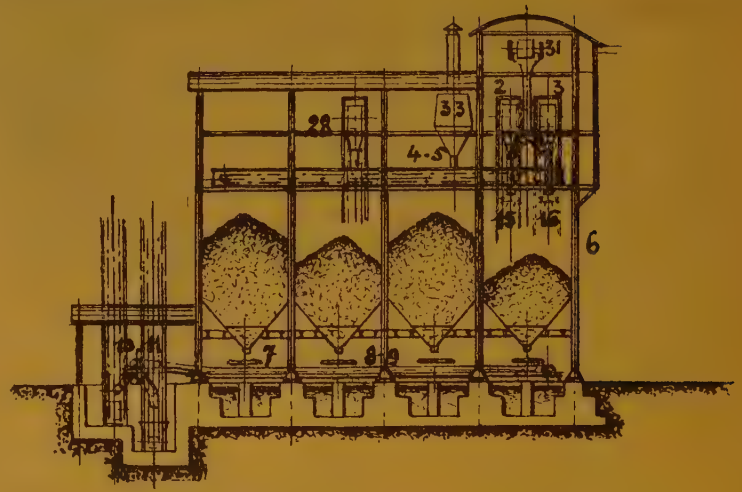


Fig. 33. — Mixing plant. — Section on NO.

Fig. 34. — Mixing plant. — General view.

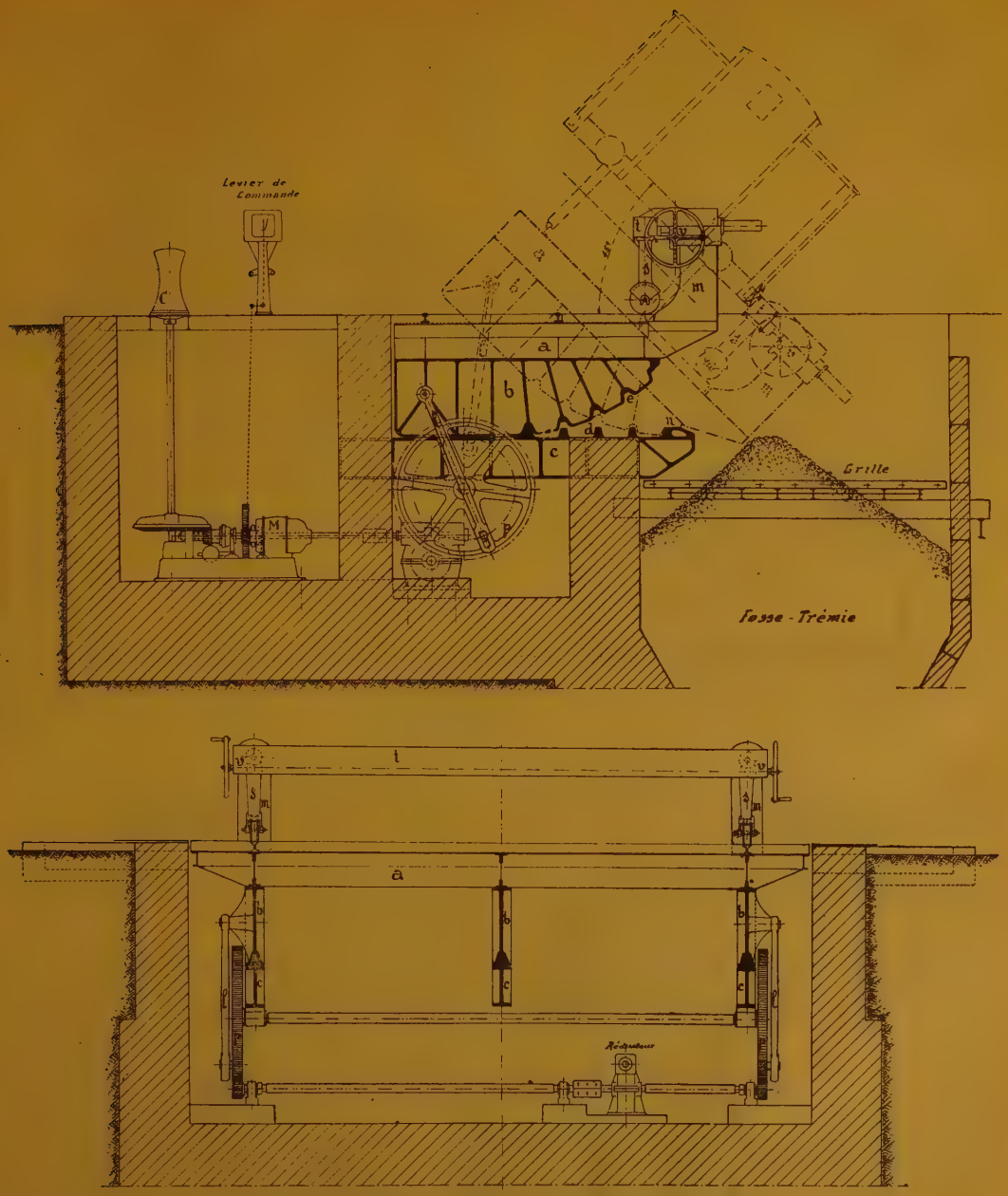


Fig. 35. — Mixing plant. — Kainscop side tippler.

Explanation of French terms : Fosse-trémie = Hopper pit. — Grille = Grating. — Levier de commande = Operating lever. Réducteur = Reducing gear.

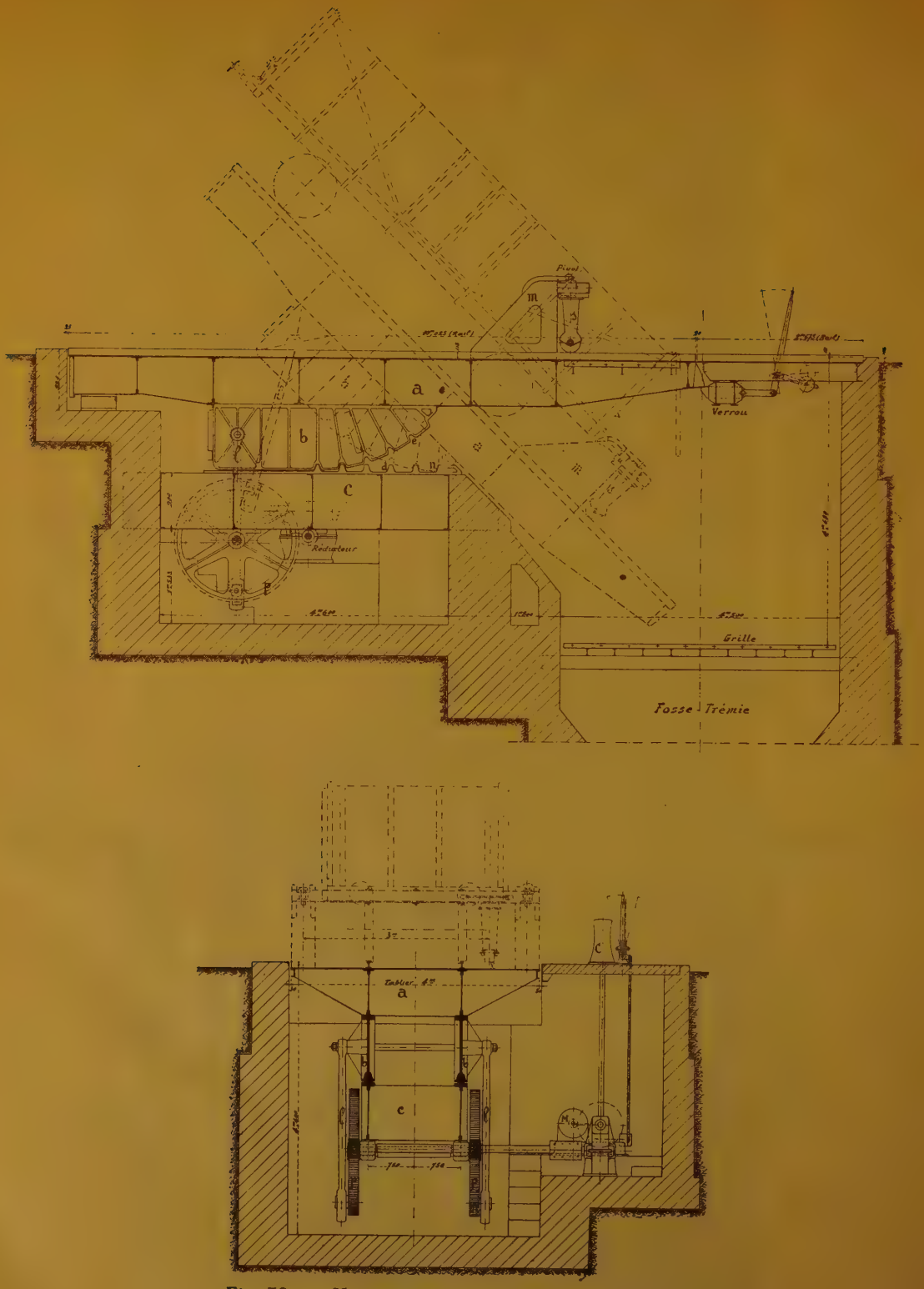


Fig. 36. — Mixing plant. — Kainscop end tippler.

Explanation of French terms : Tablier = Table. — Verrou = Lock.

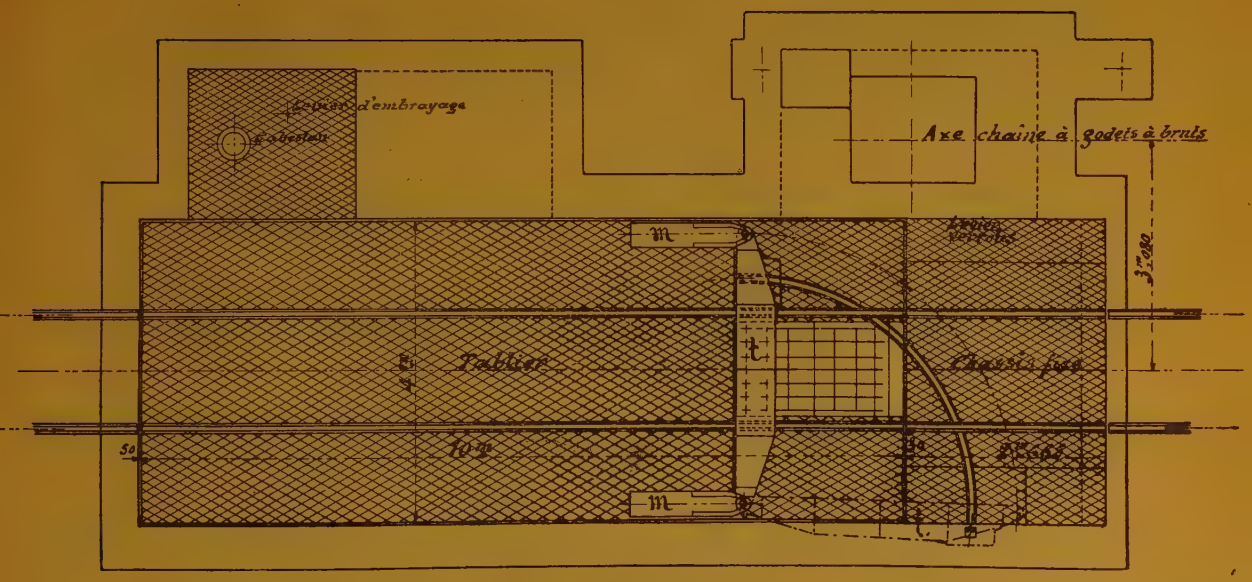


Fig. 36 (*continued*). — Mixing plant. — Kainscop end tippler.

Explanation of French terms : Axe chaine à godets à bruts = Centre line of unmixed coal bucket conveyor. — Cabestan = Capstan. — Châssis fixe = Fixed frame. — Levier d'embrayage = Starting lever — Levier verrous = Locking lever.

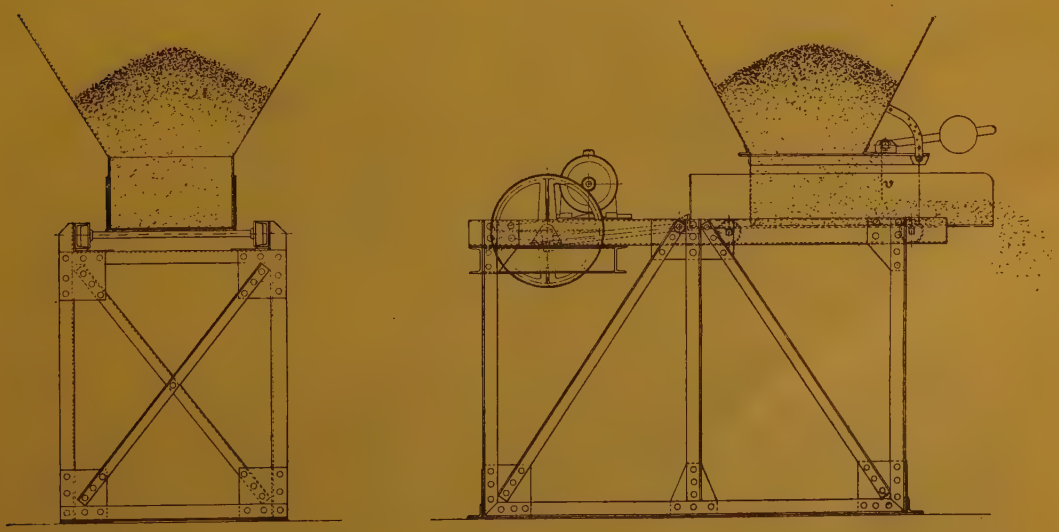


Fig. 37. — Mixing plant. — Feed hopper to bucket conveyor.

with a cylindrical casing *4* over which can slide a ring *5*, the height above the table being adjustable. The table being stopped, the coal falls on to it and makes a cone with angle α equal to the angle of repose of the particular quality of the coal. A fixed blade *6* removes a pre-determined quantity of the cone as soon as

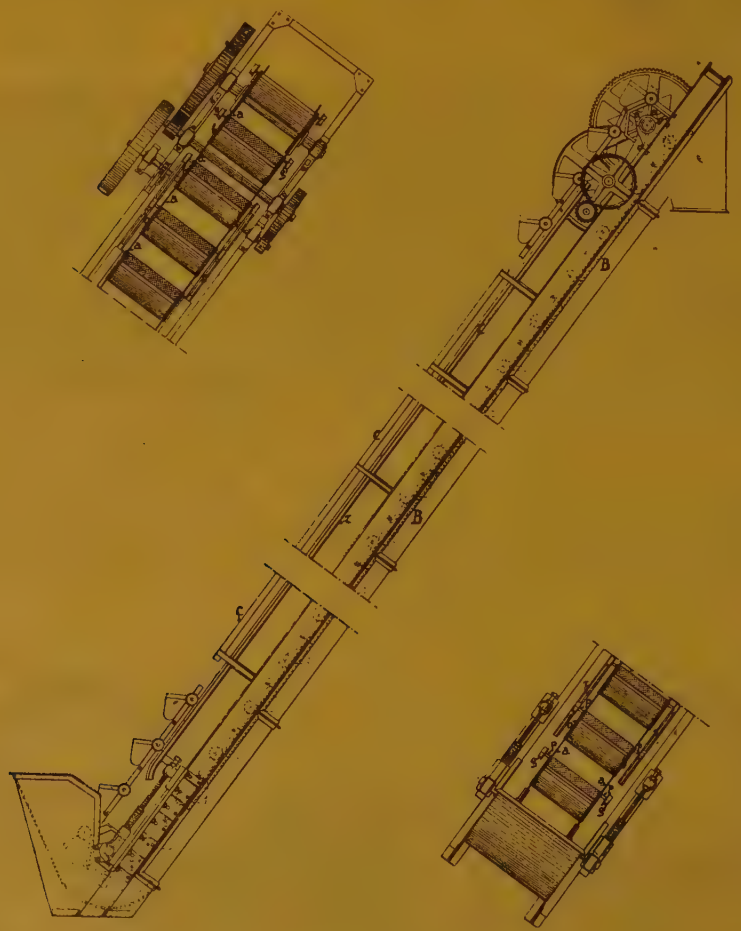


Fig. 38. — Mixing plant. — Bucket elevator.

the table is started. The blade is marked so that it can be set in any desired position to obtain any wanted mixture. The coal slides along the blade and falls by the narrow passage 7 on to the endless belt *8* running under the 4 measuring tables.

The belts in this way receive in turn and continuously coal from each of the tables, and as these are adjustable the different qualities are mixed in the proportions wanted. The tables are controlled by a single shaft. The movement is transmitted through bevel gears and a

clutch. The hourly output of each of the measuring tables is 30 tons. The two *Robins mixing conveyors* (**8**) and (**9**) have flexible rubber belts with 4 plies of canvas. Each belt is driven by a 4 H. P. motor, and its output is 60 tons an hour. The width of the rubber belt is 500 mm. (20 inches) and its speed 1.80 m. (6 feet) a second.

d) *Filling the hoppers and distributing the mixed coal.* — The coal supplied by the conveyor belts is picked up by two bucket elevators (**11** and **11'**) and delivered into one of the three silos for mixed coal (**13**) by two rake conveyors (**12** and **12'**), like those described above. The stock of coal in the hopper is about 500 tons; the hoppers are placed over the three wagon loading roads; each hopper has two valves and the wagons are filled very quickly by opening them.

2. *Arrangement of the storage yard.*

This yard is intended to make good any irregularity in the reception of different qualities of fuel, as well as to hold sufficient stocks of mixed coal, so that there is no interruption in supplying the depots if the mixing plant is out of order. It is most important that any excess coal received can be stored under a definite description to prevent any mistake occurring when used which might unfavourably affect the mixture. The stock yard should have as many bins as there are types of coal for which wagons are provided, that is, not less than $6 \times 3 = 18$.

The sketch (fig. 42) gives the dimensions of the yard at Schaerbeek and the partitions provided. The bins are described by the names given already. It will be noticed that after a certain quality of coal has been picked up, the crane can without being moved take in turn a grab of clean, average and dirty coal, so as to get the preliminary mixing according to ash content.

a) *Stocking of coal as received.* — The coal brought up by the two bucket elevators (**2** and **3**) instead of being discharged into the two *rake conveyors* (**4** and **5**) supplying the unmixed coal hoppers, is taken by the by-pass passage to the two plate conveyors (**15** and **16**) feeding the hopper supplying the monorail of the store yard. The *plate conveyor* consists of two parallel endless chains with steel plates *A* with turned over edges, which fit over one another as shewn in figure 43. The chains are like those of the bucket elevators. The plates are riveted to plates attached to the links. The rollers *g* run on rails on the frame of the conveyor. The chain is driven by the driven drum and an idler drum with an adjustable shaft.

The two plate conveyors at the store yard are driven by 7.5 H. P. motors; their output is 60 tons an hour, and the speed about 400 mm. (16 inches) a second.

The *electrical monorail* (**19**) has an endless runway with *14 motor driven Kainscop tubs.* The length is 410 m. (1 345 feet). The runway *C* carries on insulators the bar *r* (figs. 44 and 45) continuously at a tension of 110 volts. The current is three-phase, 220 volts, 25 periods, a rotary transformer of 22 H. P. supplying the motor-driven tubs which contain 1 ton. They are made of two jointed shells *a* normally closed by two sabre shaped levers *l*. The shells are opened by a catch *t* carried by the suspension gear of the tub, which butts against the fixed stop placed at the point the tub is to be emptied. When the two catches meet, the levers *l* lift through a system of intermediate levers and the shell opens under the weight of the coal. When empty, the shells fall and the

Fig. 39. — Mixing plant. — Mixing table and Robins belt conveyor.

levers *l* shut again. The tub is carried by two levers *b*, from the motor frame *m*, with the electric motor *n* of 1.3 H.P. at the reduced speed of 500 revolutions a minute with an automatic brake which stops the tub as soon as the current is cut. The current is collected by a bow *d* sliding on the bar *r*. The return is by earth; a counterbalance weight equalises that of the electric motor.

When filling the tub at the hopper (18) a short length of the monorail is

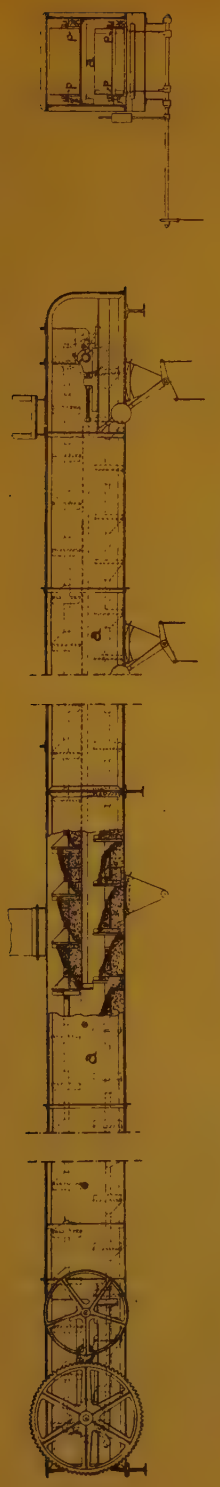


Fig. 40. — Mixing plant. — Rake conveyors.

cut out of the circuit. The tub stops below the feed valve of the hopper. The workman filling the tubs, after closing the hopper valve, switches on current, and the tub starts away. To prevent two tubs from meeting, the supply line is divided into sections of 30 m. (98 feet) length. An automatic block system prevents a tub from entering a section before the preceding tub leaves it. When passing above the hopper of the *stock goliath crane* (**20** or **21**), the catch *t* of the tub meets the fixed catch on the crane. The coal then falls into the hopper of the crane from which it passes to a rubber belt conveyor (**22** or **23**) with a *discharge cradle* by which the coal is fed on to the stack at the desired point. The discharger consists of two idler rollers over which the belt runs (fig. 46); the coal is emptied off at *A* by the centrifugal force into a specially shaped hopper *T*, and from it falls on both sides of the belt. The cradle is carried on the rollers *g* on a runway, and is secured to the rails at the off loading position so that the belt cannot move it; it is moved by a crank wheel. The stock crane is driven by a 12.5 H.P. motor at 25 m. (82 feet) a minute. The motor of the belt conveyor is 4 H.P.

b) *Stock of mixed coal.* — The coal after mixing is taken to the store by the mixing belt (**9**) beside the monorail, which, instead of emptying the coal on to the elevator feeding the hopper (**11′**) can by means of a vane take it to the foot of the bucket elevator (**10**) which empties it into a second hopper feeding the monorail (**17**). The stock coal is then handled in the same way as the unmixed coal except that a second stop catch is fitted on the tubs, so arranged that the tubs miss the first catch on the first crane, and only opens above the second allotted to the mixed coal. The two operations

can be carried out at the same time, that is to say, the monorail can stock 60 tons an hour of unmixed coal and 60 tons of mixed. The tubs with a catch on the right stop when reaching the gate valve for mixed coal, and those with it on the left at the gate valve for unmixed coal, and both only open when above the respective stock crane.

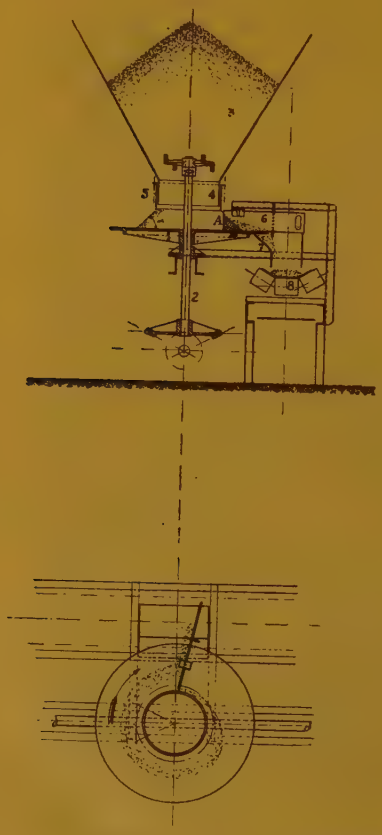


Fig. 41. — Mixing plant. — Arrangement of mixing table.

c) *Picking up of unmixed or mixed coal.* — The coal is picked up by a transporter (figs. 31 and 47) with a Priestman grab of 2 000 litres (71 cubic feet). The span between rails is 33 m. (108 feet) and the total length 47 m. (154 feet). Its hourly capacity is 60 tons. The grab, the cradle and the crane are operated by 3 electric motors of 48, 12.5 and 12.5 H. P. respectively. The speeds are 30 m. (98 feet) a minute, 80 m. (262 feet), and 24 m. (79 feet). The transporter has clips to secure it to the rails to prevent undesired movements, especially in rough weather, and has jacks for lifting it when the carrying wheels require attention.

The transporter has a hopper *T*, which is fed by the picking up plate conveyor (**26**), (fig. 48) of 60 tons an hour capacity running the whole length of the storage yard. This conveyor feeds on to the bucket conveyor (**28**) or (**27**), depending on whether unmixed or mixed coal is being taken up. These conveyors deliver the coal on to one of the rake conveyors, which empty it into the hoppers.

The picking up transporter can be used to off-load unmixed coal directly to the stock, or to load the hoppers by means of the picking up plate conveyor, so as to act as a relief to the tipplers and quicken up the unloading of the wagons. The transporter can also pick up mixed coal and load it directly into wagons at the rate of about 60 tons an hour.

C. — Output of the plant.

The rake conveyors and the mixing belts, having a maximum output of 120 tons an hour, the normal output is limited to this amount. The two elevators from the side tippler, and the elevator for the end tippler have each a capacity of 120 tons an hour. They cannot be used together when off-loading coal into the unmixed coal hoppers. One of the tipplers can be allotted to the off-loading of coal for immediate mix-

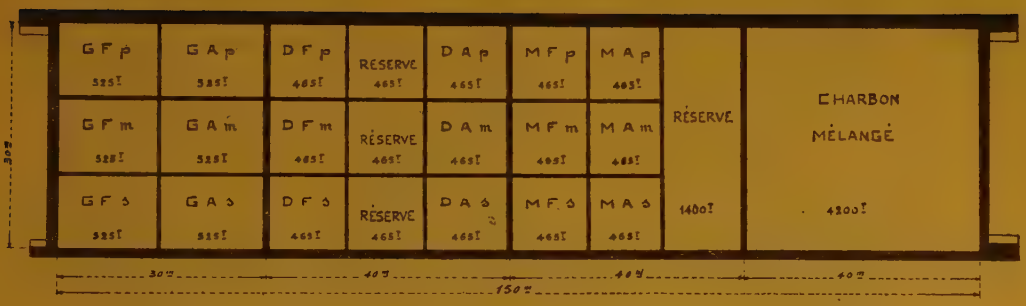


Fig. 42. — Mixing plant. — Arrangement of coal storage ground.

Explanation of French terms : Charbon mélangé = Mixed coal.

Classification of coal from the point of view of

Volatile matter:
- *G* = Bituminous.
- *D* = Semi-bituminous.
- *M* = Semi-anthracite.
- *F* = High volatile content.
- *A* = Low — —

Ash content:
- *p* = Low.
- *m* = Average.
- *s* = High.

The capacities are given without excess loading (coal level with the walls.)

ing, whilst the other is off-loading wagons of coal for stock. As we have noted, it is hardly practicable to get up to the output of 120 tons an hour at the side tippler; on an average it is only possible to count on 80 tons.

The *storing of unmixed coal* can be done at the rate of 120 tons an hour by using simultaneously both cranes above the same part of the store yard. To some extent this stocking can be done whilst the unmixted coal is being loaded on to the hoppers, as we have already noted.

The *stocking of mixed coal*, less frequently necessary, can be done at the rate of 60 tons an hour. Care is taken to send the mixed coal straight away to the consuming points where, if necessary, it is stocked locally.

The stocking of unmixed or mixed coal can be done at the same time at the rate of 60 tons an hour, as we noted when describing the monorail. If any kind of coal is not received in sufficient quantity, the *picking up of coal* can be done by the transporter at the rate of 60 tons an hour. The *picking up* is done by taking a grab full from each of the compartments of the store set aside to these kinds of coal, so as to get the preliminary mixing as regards ash content.

The *picking up of mixed coal* is done at the rate of 60 tons an hour by the transporter. The coal can be loaded into ordinary or hopper wagons by the grab, or sent to the distributing hopper by means of the plate (**26**) and bucket (**27**) conveyor. The transporter can also be used to *unload directly the wagons of unmixed coal* on the two first lines alongside the stock. The output of the grab is 60 tons an hour. This method has advantages when wagons with only one door on each side and without end doors are

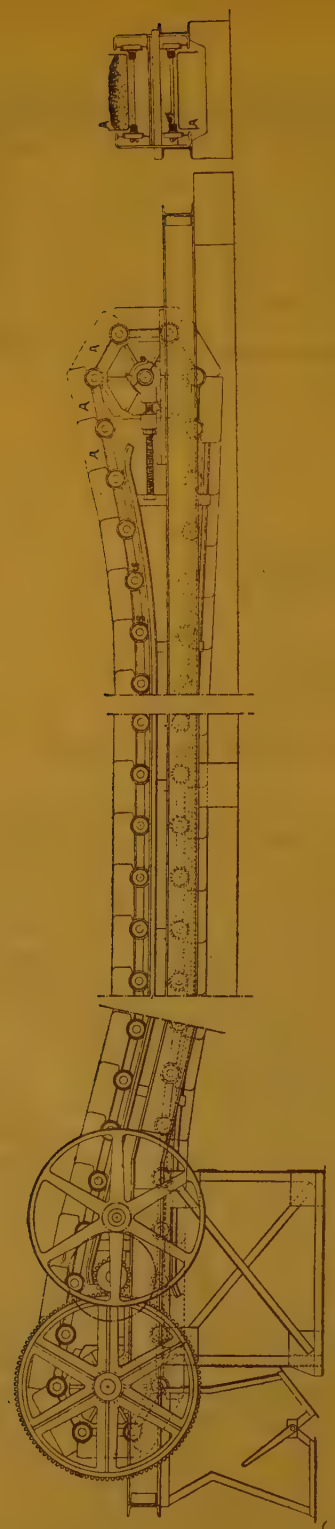


Fig. 45. — Mixing plant. — Plate conveyor.

received, and particularly so when the coal is damp. The coal can then be emptied directly into the section allotted to it, or sent to the hoppers by the picking up plate conveyor.

It will be seen that the plant is very adaptable, and that the different operations can be done together or combined, so that under all conditions the desired mixture is obtained.

D. — Staff.

For the output of 120 tons an hour, a gang of seven labourers is required, divided as follows : 4 at the tippler for handling the wagons; 1 at the elevator for the unmixed coal, the working of the inlet valves in the 4 hoppers for unmixed coal, the attendance to the building above these hoppers; 1 at the measuring tables and the mixed coal elevators, and the inspection and cleaning of the building in which the hoppers of mixed coal are installed; 1 loading the mixed coal into wagons. Each gang is under a chargeman fitter responsible for the working and output of the plant. A foreman is responsible for supervising the working of the plant. In each gang there is also a man who can work the equipment at the store yard which is only used intermittently. This man has also to attend to the upkeep, greasing and cleaning of the plant in between times. The inspection and repairs of the whole plant are covered by a fitter per gang. In addition, to get the 2 000 tons required daily, two shunters and two labourers are needed per day to mark off and sort out the wagons of unmixed coal, as well as to cover the weighing and despatch of wagons loaded with mixed coal. A shunting engine is available for shunting and despatching wagons whilst the men are on duty.

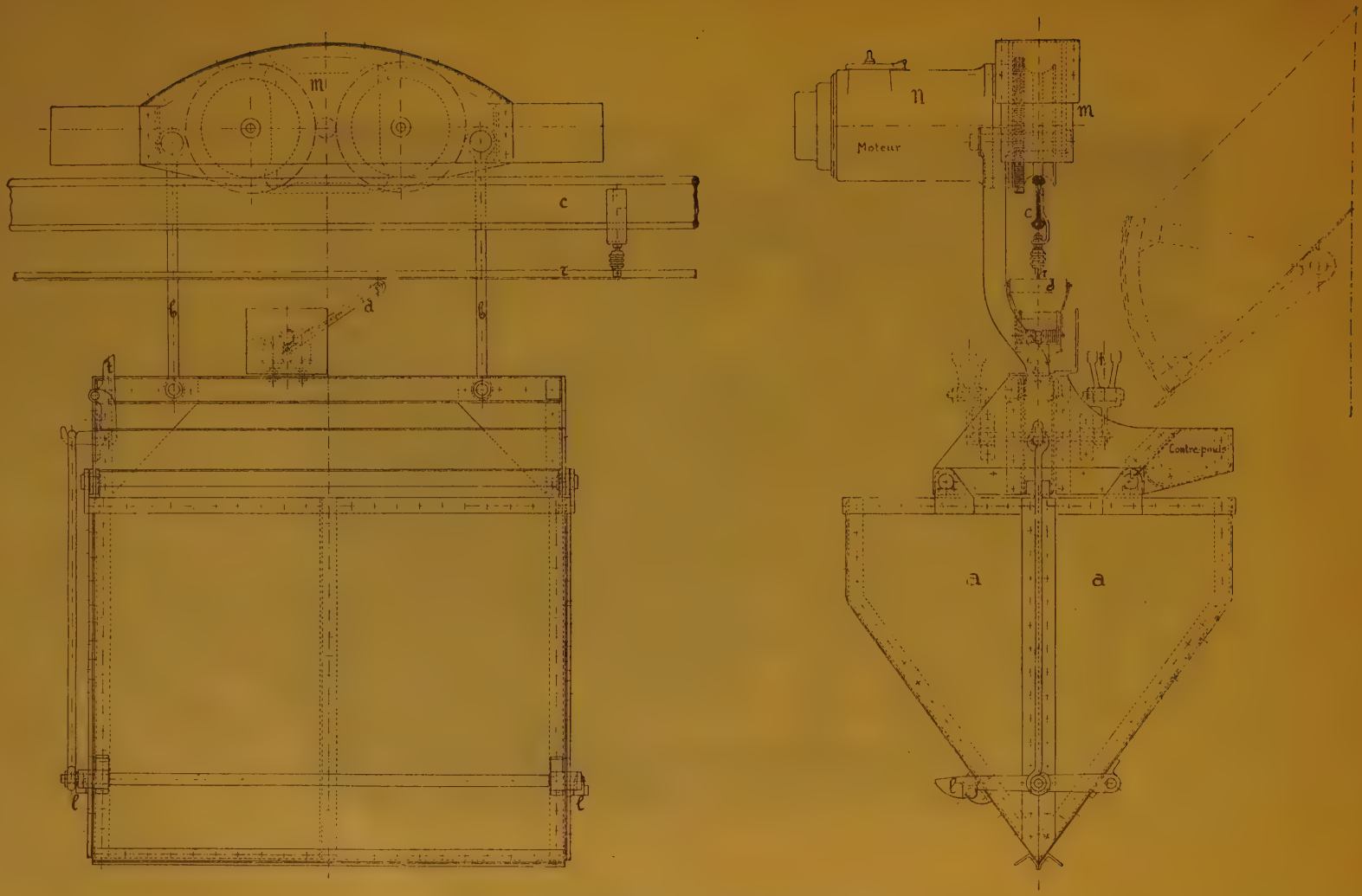


Fig. 44. — Mixing plant. — Kainscop automotor tub.

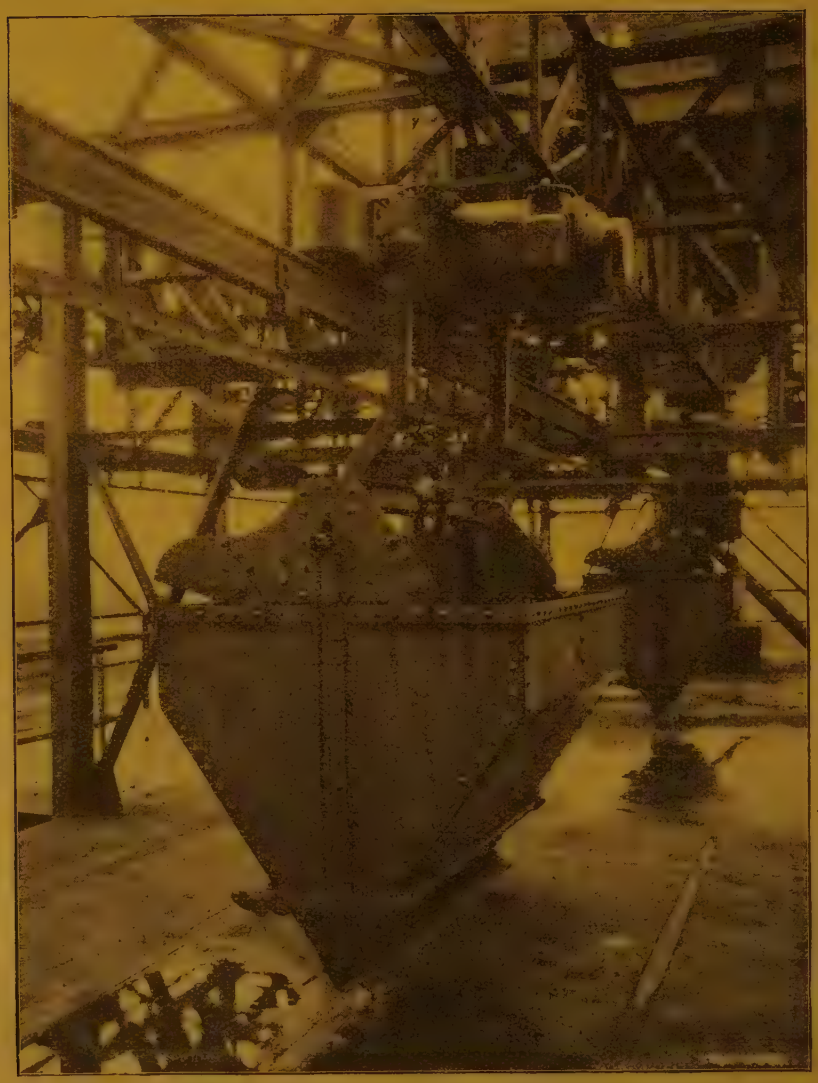


Fig. 45. — Mixing plant.

Kainscop automotor tub holding 1 200 litres (42.38 cubic feet).

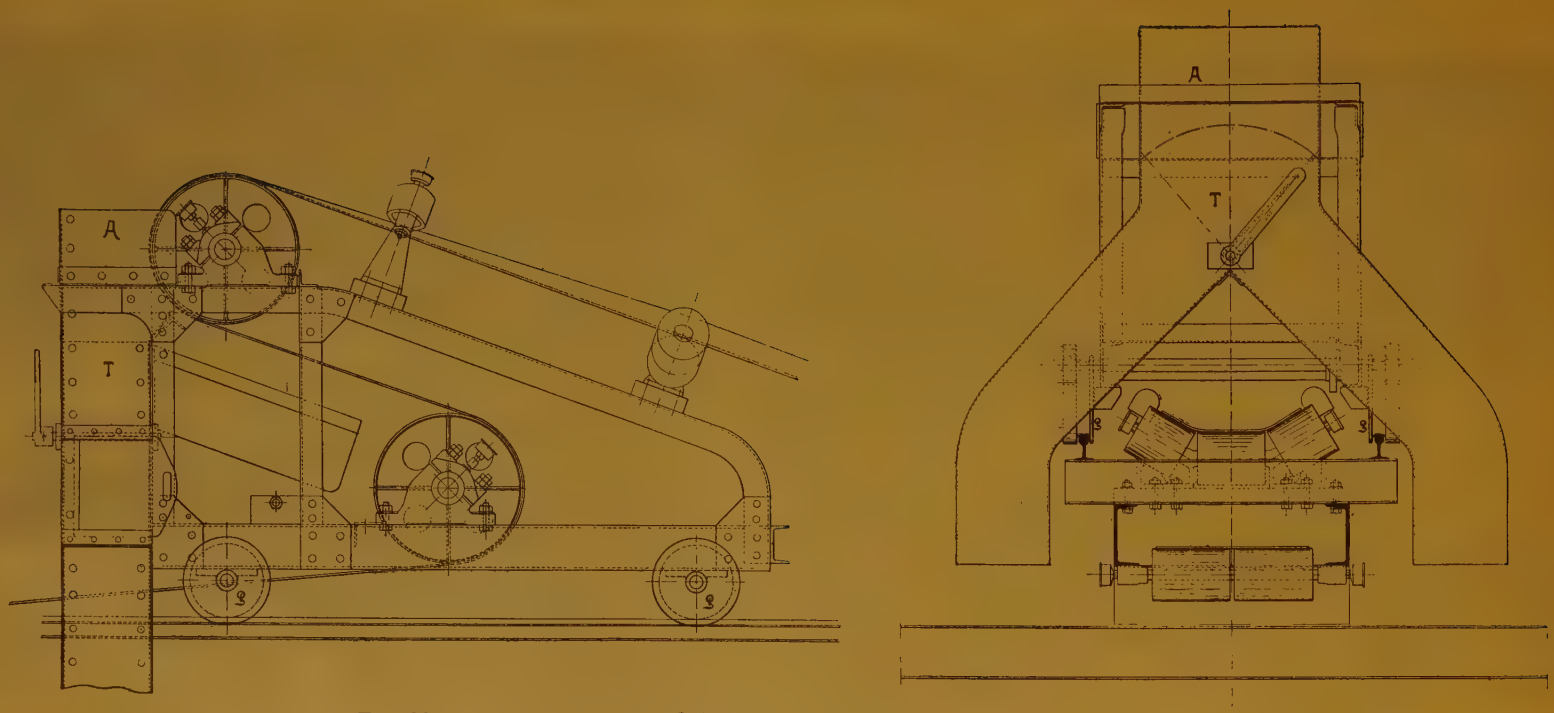


Fig. 46 — Mixing plant. — Offloading cradle on crane supplying coal to stock.

Fig. 47. — Mixing plant. — Stock-yard, picking up crane and stocking crane.

Fig. 48. — Mixing plant. — Coal picking up plate conveyor.

PERIOD.	1	Consumption slack coal, in tons. 2	Consumption briquettes, in tons. 3	Consumption lump, in tons. 4	Total consumption, in tons. 5	Percentage slack to total consumption. 6	Total number of ton-kilometres hauled. 7	Total consumption per ton-kilometre, in grammes. 8	Consumption taking into account evaporative power, in grammes. 9	Percentage saving on second half of 1924. 10
2nd half 1924		39 080	6 339.4	5 425.9	50 845.3	76.9	616 070 107	82.5	86.3	...
2nd half 1925		40 049.5	10 630.7	1 659.1	52 339.3	76.5	658 761 254	79.4	83.1	3.71
1st half 1926		40 277.9	11 806.7	394.4	52 479.0	76.7	689 656 593	76.1	79.6	7.76
2nd half 1926		40 378.1	7 884.9	4 658.4	52 871.4	76.6	711 435 897	74.3	77.8	9.85

E. — Motive power.

The total power is about 330 H. P. The only motors in the plant running more or less continuously are those driving the elevators, the rake conveyors, and the belts for unmixed and mixed coal. The other motors are run irregularly. The average power used is about 120 H. P.

F. — Cost price.

In 1926 the plant was worked with three shifts so as to get an output of 1 800 tons a day. The cost per ton of mixing was then 2.80 fr.; this price includes wages and bonus (0.66 fr.); repairs, labour and material (0.12 fr.); general charges in connection with the operation and upkeep of the plant (0.08 fr.); interest and depreciation of first cost (1.16 fr.); motive power (0.48 fr.); cost of shunting (0.30 fr.). The end tippler enabled the same output to be got when working two shifts, and reduced the number of men and the use of a shunting engine by a third. The cost per ton was brought down to about 2.50 fr.

G. — Savings effected.

At the beginning we noted the necessity for mixing the different kinds of small coal the Belgian railways had to use. Until recently the mixing was done haphazardly, either when off-loading on to the stack, or when coaling the tenders. A mixture under such conditions could not be guaranteed, and the costs with such rough and ready methods, even if they cannot be accurately arrived at in an undertaking as complicated as a railway, were none the less considerable. On the other hand, it is just as certain that very large savings are realised by using fuel prepared methodically, ra-

tionally and cheaply, with those qualities tests have proved to be most suitable to give the best results in locomotive fireboxes.

The Schaerbeek plant produced in 1926 about 434 000 tons of mixed coal, that is, rather less than a quarter of the total annual consumption of small coal on the system. The Kainscop Company are now finishing off the erection of three other central plants which, with that at Schaerbeek, will provide all the mixed coal required by all the depots.

The Schaerbeek depot has been supplied regularly with mixed coal since the second half of 1925. The average consumption of fuel at this depot per ton-kilometre hauled during the second half of 1925, and the two half years of 1926, is given above and for comparison those of the second half of 1924 preceding the starting up of the plant.

The total consumption per ton-kilometre in column 8 is obtained by adding together the three kinds of coal which have different evaporative power. If the evaporative power of the small coal be taken as 1, and if that of the briquettes and lump be 1.2, the mixed coal of 76.9 % slack and 23.1 % briquettes and lump, for example (2nd half of 1924) will have an evaporative power of $0.769 + (0.231 \times 1.2) = 1.0462$, and the consumption, taking this factor into account, will be $82.5 \times 1.0462 = 86.3$ gr. per ton-kilometre. The values of the consumption determined in this way are given in column 9 and have been used to shew the saving made with regard to the second half of 1924.

At Schaerbeek depot, in the course of two years the consumption per ton-kilometre has fallen 10 %. Naturally other factors than the mixture of the coal, such as the state of repair of the engines, the increase in the daily length of haul, and the make up and load of the trains hauled affect this reduction. It is consequently impossible to determine the exact saving due to the use of the mixed coal. With regard to certain of the above factors, it was only at the end of the second half of 1926 that the above improvement was realised at Schaerbeek, so that it can be concluded that the rate of saving from the use of mixed coal is large, and has continued to increase as the product of the plant has improved.

If the cost of preparing the mixture is only 2.50 fr. everything included, or 1.5 % of the cost of the small coal, the cost of mixing is paid for if only a slight saving in the consumption is made.

All the services using mixed coal from Schaerbeek report the improvement obtained in firing from its use when working trains, as it can be used in the most rational way it is not only economical but is also regular in composition. This last quality is essential; putting aside any idea of economy, a correct mixture is necessary on our system, perhaps more than on any other, owing to the great diversity of quality of our small coals. If the differences of the past as regards mixture were continued, delays, lack of steam, failures, and excessive consumption might result with the usual considerable increase in cost of operation. In the near future all the depots on the Belgian system will be supplied with mixed coal from four central plants; there is no question but that the results will confirm the savings given above, and that this plant has to be included amongst the essential measures taken by the Belgian system with a view to operating trains economically.

[625 .143.5]

Automatic heat and cold work surface hardening of rails in service,

By Mr. SABOURET,
CHIEF ENGINEER, BRIDGES AND ROADS,
CHIEF ENGINEER OF TECHNICAL SERVICES OF THE ORLÉANS COMPANY.

Figs. 1 to 15, pp. 514 to 531.

(*Revue Générale des Chemins de fer.*)

SUMMARY : I. *Accident owing to a rail fracture at Grisolles.* — II. *Appearance of cracks and investigation thereof.* — III. *Superficial hardening by heat or mechanical action.* — IV. *Note on the facts and enquiry into the causes* — V. *Remedies.*

I. — Failure of a rail at Grisolles.

An express train from Cette to Bordeaux came off the line on the 8 November 1908 in the station of Grisolles, between Toulouse and Montauban, when over an ashpit, through a rail breaking into 21 pieces. The failure of the rail was in consequence investigated by three particularly well qualified experts: Mr. J. Resal, Professor at the « Ecole des Ponts et Chaussées », Mr. Chesneau, Professor at the « Ecole des Mines », and Mr. Cellerier, Director of the test house at the « Conservatoire des Arts et Métiers ».

A summary of their report with photographs was given in the *Technique Moderne* (June 1910) by Mr. Cellerier, one of the experts, and Mr. Breuil, his assistant at the Conservatoire.

The metal of the rail was sound and of normal composition, except for a slight excess of phosphorus. The double headed rail was very little worn, although it had been in service for twenty five years on a line with much traffic. Its surface was hardened about the inside radius. A zone of metal of very fine grain 7 mm. (9/32 inch) thick was found between the hard surface, which was from 0.5 mm. (0.02 inch) to 1 mm. (0.04 inch) thick, and the unaffected metal.

The superficial hard layer was full of cracks across the rail, some penetrating deeply into the rail head.

The rail shewed many wheel slip marks of the driving wheels when starting on the pit.

Bend tests were made with test pieces cut from the rail supported on two bearings 0.60 m. (24 inches) apart. The first test with the hard layer upwards under a load of 107 tons, deflected 114 mm. (4 1/2 inches) without breaking. A second test piece with the hard layer downwards broke under a load of 48 t. On repeating this second test with a test piece, after planing off the hard layer, the breaking load exceeded 48 t.

The experts agreed that the fine cracks were due to the hard surface layer, which is much less ductile than the underlying metal. They ascribed the formation of this layer to a hammering of

the metal caused by wheel slipping.

With the approval of the Inspection Branch and of the Technical Operating Commission, the Minister, by a letter dated the 13 January 1911, called the attention of all the Railway Companies to the circumstances of the accident and asked them : 1. to prepare standard specifications for the manufacture and inspection of rails ; 2. to take special precautions so as to prevent, as far as possible, the failure of rails at inspection ash pits or at the usual stopping places.

The letter added that it dealt with « a phenomenon which did not appear to have been suspected previously. »

The conclusion to be drawn from the Grisolles affair was that the superficial fine hair cracks of the rail accompanied by penetrating cracks was due to a hammering action due to frequent slipping of wheels on phosphorous rails.

A metal is said to be *work hardened* when it is hardened *cold* or at a low heat, by *mechanical* work, such as extruding, drawing, hammering, or rolling.

The theory of work hardening was immediately contested by one of the leading metallurgists of the period, Osmond, Professor at the Sorbonne. His letter to Mr. Breuil was published in the February 1911 number of the *Technique Moderne*. As against the theory of cold work hardening, Osmond suggested a superficial *automatic heat hardening* due to *heat action*. The principal passages of this important document are reproduced below.

In the June number of the *Technique Moderne* you published an article on the fatigue of metals, and in it you speak of a rail which under microscopic examination shewed a superficial layer clearly reproduced in figures 3 and 4. You think this layer to be cold work hardened. Are you really certain ?

The flaking parallel to the surface proves that the top of the rail head has been cold work hardened. But it seems to me very doubtful that the well marked line separating the upper light grey part from the lower cristalline zone is a line of demarcation between an area much work hardened and another less so.

. . . . . .

The case seems to me to be exactly the same as that of the broken rail which caused a serious accident at Saint-Néots, in England, about fifteen years ago. Roberts-Austens asked me to examine the rail, and the photographs taken resemble yours. If the phenomenon is also the same, it is a question of surface hardening by heat. The heating has, however, been so rapid that the carbon has not had time to diffuse itself. The perlite has been changed into hardenite, with a border in places of troostite where diffusion has begun.

These results can only be explained by a violent frictional effort lasting several instants, such as slipping of driving wheels, or running with the wheels skidded by the brakes. The layer, heated above the critical temperature, is extremely thin, and has cooled off sufficiently quickly by conduction for it to become hardened.

. . . . . .

Mr. Frémont accepted the theory of self heat hardening in an article on the manufacture of rails (*Génie Civil*, 13 May 1911) and has since dealt with it in four recent papers, numbers 58 and 59 of 1921, 61 of 1922, and 69 of 1924. Whilst accepting Mr. Osmond's views, Mr. Frémont has laid stress on the effect of interior defects in the rails on which wheel slipping has occurred : « The flaws extend towards the interior of the rail, the weak points due to impurities assisting the extension in depth (Paper 58, page 48) ». « The hair cracks in the metal are only really dangerous when the underlying metal is brittle or segregated (Paper 59, page 44) ».

In August-September 1921, Mr. Charpy, member of the « Académie des Sciences », Professor of Metallurgy at the « Ecole des Mines », and Mr. J. Durand, wrote a

paper « A cause of rail breakages and a method of preventing it. » The cause is the superficial hardened layer which they attribute to cold work hardening as in the case of the Grisolles rail. They suggest that the hardening is only found on old rails, and that it is due to « ageing ». To remove this hardening they suggest the surface be heated by means of portable appliances. The conclusions of Mr. Charpy and Mr. Durand have been contested by Mr. Frémont in his Paper No. 59 (page 42).

It is obvious that the leading French metallurgists are far from being in agreement on the formation and the danger of hair cracks and cracks of the top of rails (1).

The Engineers of the Paris Orléans Company have given much thought to the failure of the rail at Grisolles ever since it was brought to their notice by the Ministerial letter of January 1911. The same year Mr. Chagnoux, Engineer of the Company, devised the method given below by which the cracks could be reproduced.

Cracks caused by wheel slips at starting are not the only ones found on the surface of rails : many more are produced by cold work hardening, and can be divided into classes by their form and by their cause. They are not caused by the ordinary running of the trains; as we shall see later on, they arise out of defective operating methods, which can be of many kinds.

The mere fact that the superficial transverse cracks of rails had not been noticed by the staff of the French railways before the Grisolles accident shews better than anything else how difficult it is to discover these cracks and to investigate and classify them by their causes, and by the degree of danger they present.

(1) The words « hair cracks » are used to describe fine cracks of little depth such as those in figures 4 and 5.

The War, and the subsequent unsettled years, interrupted the investigations started with the usual uncertainty of such work. The enquiry was again taken in hand by the Orléans Company in 1921 : the first programme drawn up provided for laboratory tests, and laid down the method of testing by wheel slipping, as described later on.

This method was first used in 1924 in the yard at Juvisy, to compare the relative tendency of rails from the same ingot, some heat treated after rolling and others untreated, to become surface tempered.

Two accidents in 1925 on the Orléans Railway, attributed to the breaking of rails shewing signs of wheel slipping, hastened the investigation, the conclusions of which are given herein, although they are only provisional and open to dispute, as the subject is far too complicated to be cleared up so quickly. It is to be hoped that these observations on the problem will give rise to others, as the solution requires many and long sustained efforts, especially when drawing up regulations as to leaving in or withdrawing from service cracked rails.

II. — Appearance and investigation of cracks

As superficial defects are under consideration, it will be as well to examine their usual appearance which is shewn in figures 1 to 10.

The first four figures are of tests taken from rails in which, owing to wheel slips having occurred when starting, there has resulted superficial heat hardening. Figure 1 shews the effect of a single slip. In figures 2, 3 (rail from Arpajon, chap. IV, § 10.) and 4, slipping has occurred at different times, and the cracks have increased in number and extent. The hair cracks seen in figures 3 and 4 are due to cold work hardening

immediately below or above the heat hardened part.

Figures 5 and 10 were taken from work hardened rails. The hair cracks or very fine cracks of figure 5 (like a snake skin) and 6 (innumerable commas) are found in rails laid on the straight or on the outer rail of curves and are of little depth.

The prints (figs. 7 to 9) were all taken from rails on the *inside of sharp curves,* over which goods trains ran *at slow speeds.* The increase in load due to the curve, and the skidding of slipping driving wheels or picked up wheels, have crushed, spread, and, as it were, rolled out the top of the rail, loosening the top layer. The rolled out layer in figure 7 is not yet cracked. The oblique cracks of figure 8 are found on the lower rail of sharp curves on steep *down grades,* and the usual cracks of figure 9 on the low rail on severe *up grades.* Cracks of these kinds affect the surface on which there has been slipping, and do not penetrate into the remaining metal.

The print (fig. 10) is from a rail on the straight on the shunting neck on to the hump in the marshalling yard at Juvisy. This rail is frequently subjected to the effects of the wheels of the shunting engines slipping and sliding along it.

Principal observation. — The area shewing hair or other cracks in all these rails on which slipping has occurred is considerably hardened. The resistance of the metal in these areas, tested by the Brinell method, is from 120 to 180 kgr. on the rails heat hardened and 90 to 120 kgr. on the rails work hardened. All these rails are made from steel of 70 kgr. quality (44.5 English tons per square inch).

For instance, the Brinell-Turpin figures for the Arpajon rail were : 137 kgr. on the heat hardened area of the inside edge, 110 on the central area work hardened, and 74 outside these zones. A vertical section through xx' across the heat hardened area revealed the depth of the cracks, one of which was 8 mm. (5/16 inch). On the other hand, the hair cracks due to work hardening across the vertical section through yy' had not penetrated any appreciable depth.

Rails much work hardened or on which there has been much slipping wear little during long service owing to their surface hardness.

Investigation. — It has been noted above that the staff had not noticed these cracks until recently. After proper training and instruction it is usually possible to see them with the eye without any special treatment of the surface. It must be admitted that the most careful and well informed staff cannot locate them, and above all cannot form correct opinions on them, except after a very prolonged personal experience only to be expected from specialists.

When cracks are suspected on rusted surfaces, emery cloth or carborundum is used to polish the surface.

Washing with plenty of water increases the visibility of the cracks on a bright rail. A good angle of reflection should be found, care being taken not to look at the rail when facing the sun.

The most useful instrument to use when testing the hard surface of rails is the Brinell-Turpin ball apparatus introduced on the Paris-Orléans Railway by Mr. Pons, Engineer in charge of Fixed Plant and Stores. By the use of standard small steel cubes, the apparatus enables the Brinell hardness to be ascertained by a blow of a hammer sufficiently light to neutralise the effect of the underlying metal. The Turpin apparatus packs into a case measuring 11 cm. by 11 cm. (4 3/8 by 4 3/8 inches) weighing 600 gr. (1.32 lb.) and is really portable.

A very accurate record of the cracks

STATE OF SURFACE OF RAILS WITH FINE CRACKS OBTAINED BY THE CHAGNOUX PROCESS.

Automatic heat hardened rails after slipping.

1. *Single slip, fine cracks hardly visible.*

2. *A number of slips, very many fine cracks.*

3. *A number of slips, many fine cracks with hair cracks from cold work hardening as well.* (Arpajon.)

4. *Old slips, with cold work hardening hair cracks superimposed.*

Cold work hardened.

Rails on the straight or the upper rail on a curve.

5. *Fine hair cracks.* (*Snake's skin of* Pierre Buffière).

6. *Innumerable commas.* (Lioran.)

Rails crushed on the lower side of a sharp curve.

7. *On down gradient, without fine cracks.*

8. *On down gradient, with oblique fine cracks.*

9. *On up gradient, with normal fine cracks.*

Clermont to Royat.

Rail on the straight.

10. *On the uphill shunting neck in the marshalling yard at Juvisy.*

N. B. — *The prints are shown with the outside edge of the rail upwards.*

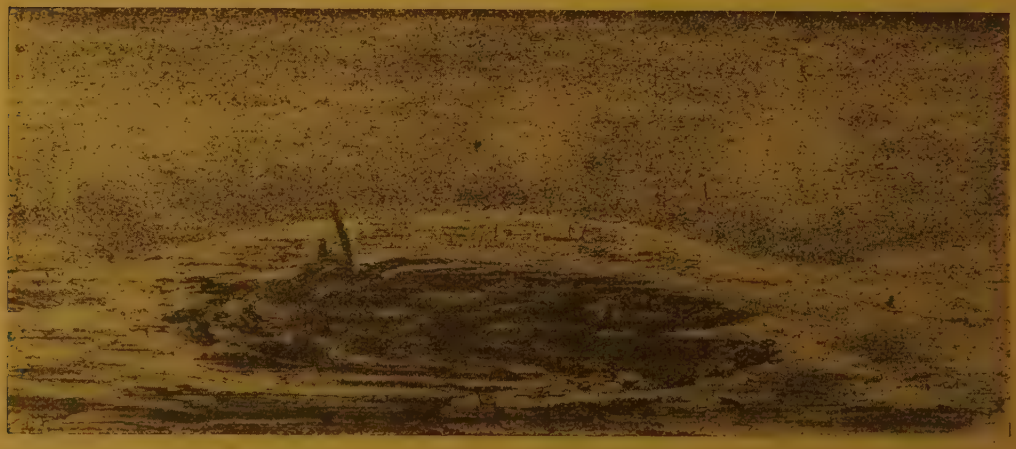


Fig. 1.

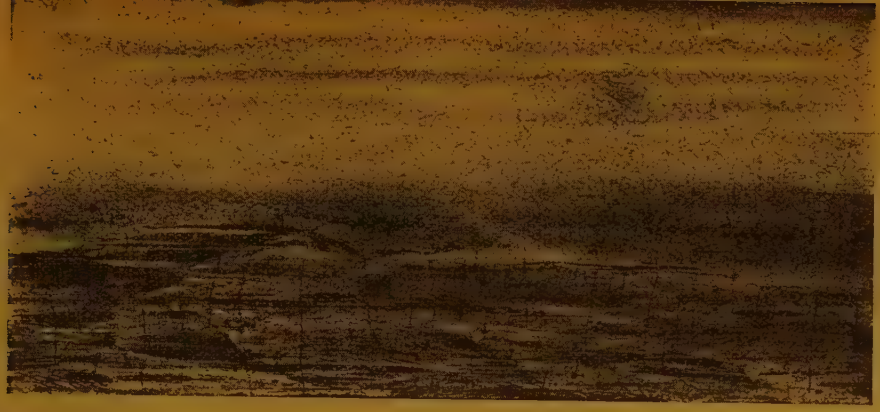


Fig. 2.

Fig. 3.

Explanation of French terms: Coupe XX' = Section XX'.

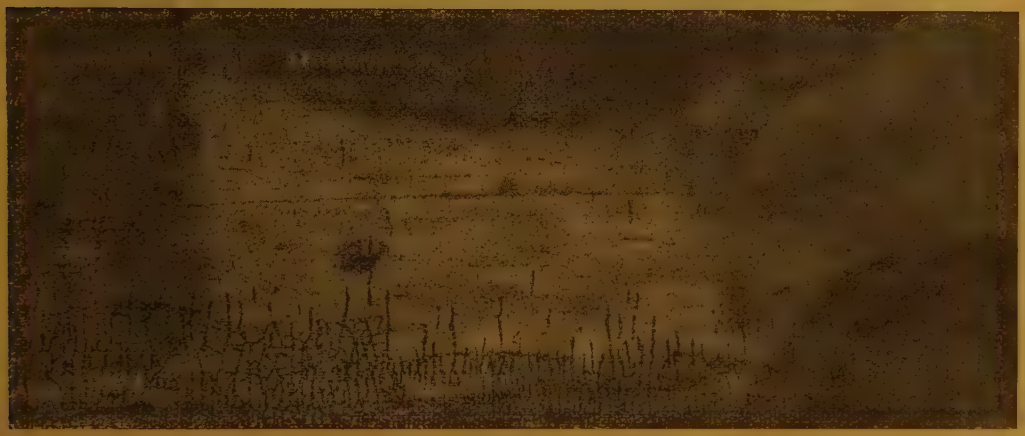


Fig. 4.

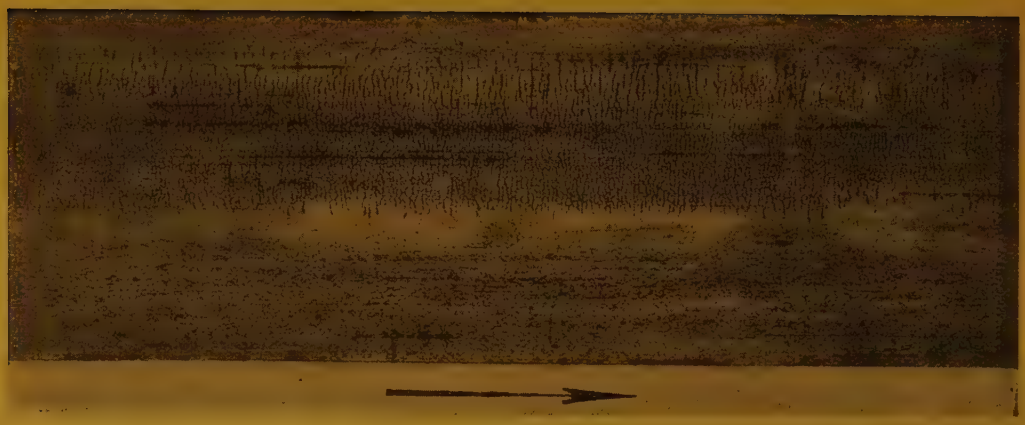


Fig. 5.

Fig. 6.

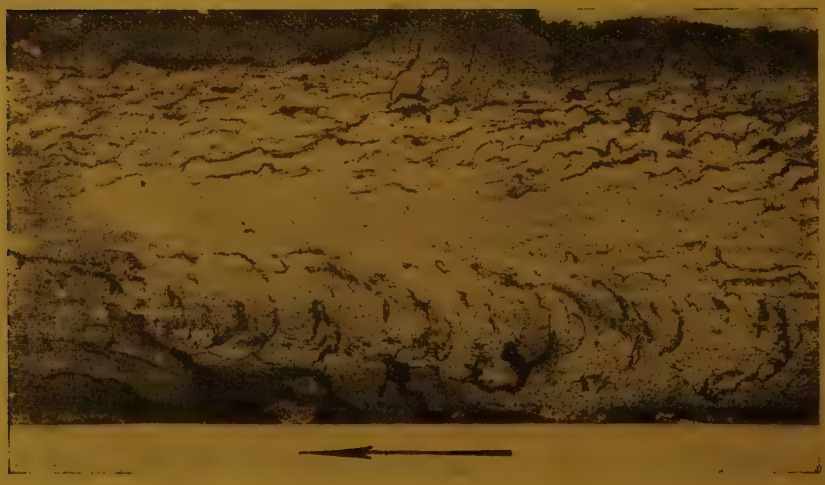


Fig. 7.

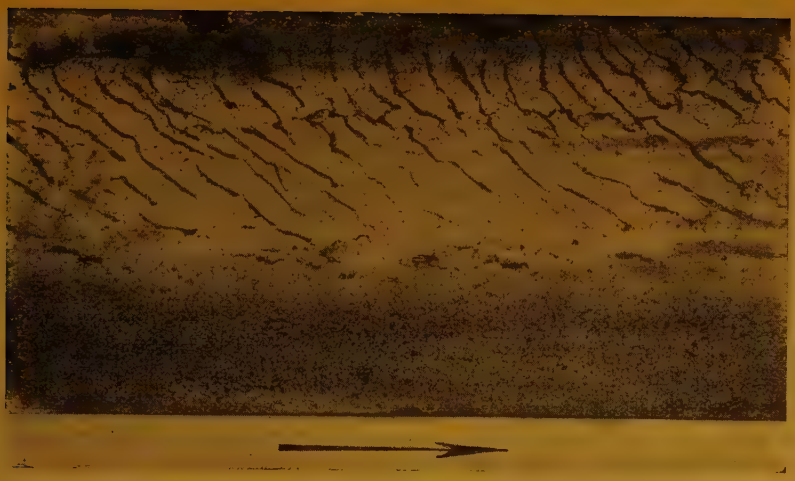


Fig. 8.

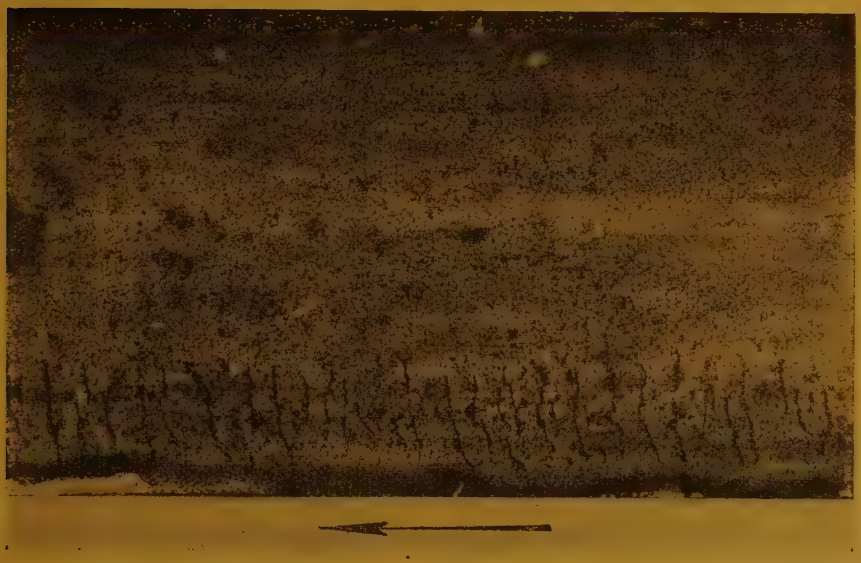


Fig. 9.

Fig. 10.

is essential for their investigation. Direct photographs can only be taken in the laboratory, whereas it is very desirable to take a record of the cracks from rails in place in the track. The record from the track is made by applying bromide paper, soaked in slightly acid water, to the rail, after polishing it and rubbing it with barium sulphide, which penetrates into the cracks.

The Orléans Company preferred the method devised by Mr. Chagnoux, an Engineer in the Chief Mechanical Engineer's Department. His method, one of great perfection, consists in preparing the surface of the rail as if it were a steel plate for engraving. The rail is polished : the cracks are marked by treating for a short time with nitric acid : the rail is cleaned : printers' ink is smeared over it : it is again cleaned : finally, by means of a small portable press prints are taken on non adhesive paper. The rail cannot be used for traffic for about ten minutes. All the prints dealt with above were taken in this way.

III. — Superficial hardening by heat action and by cold working.

Effect of a hard superficial layer. — However caused, whether by heat or by cold work, the superficial hard layer has insufficient or no ductility : it barely yields under tension, whether due to a rise in temperature or to mechanical stress. As the mass of the head has a high co-efficient of extensibility, the inextensible surface layer breaks when the head is stretched by the load of the wheels.

In a continuous girder supported on many bearings like a rail, at any given point the head of the rail is alternatively in compression and in tension. It is in compression under a load immediately above this point, and in tension when the point lies between loads separated by one or two sleepers. In the case of figure 11, the maximum extension occurs above sleeper 2; with figure 12 the extension is uniform between sleepers 5 and 6.

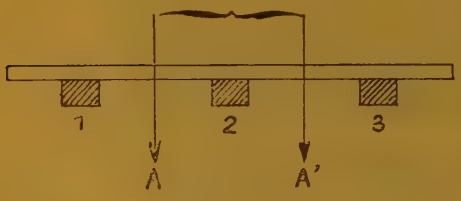


Fig. 11.

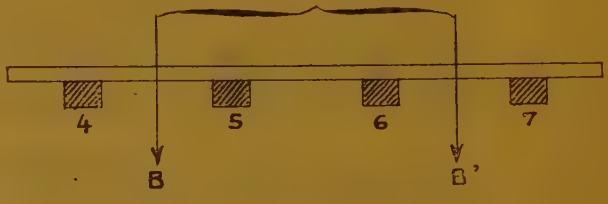


Fig. 12.

The stress reversal which occurs with rigid sleepers is increased under a passing train if the sleepers 1 and 3 are depressed more than sleeper 2, or the sleepers 4 and 7 more than 5 and 6.

Superficial heat hardening. — A steel is said to be of *tempering quality* if it hardens and loses its ductility when quenched in cold water after having been heated above 850° C. (1 562° F.).

The results of hardening depend on the composition of the steel and on the temperature and kind of liquid in which it is quenched. All steels so far used for making rails can be hardened.

It will be seen later on that tempering rails of 40-45 kgr. (25.4 to 28.6 English tons per square inch) quality hardens them very slightly, whilst preserving the ductility of the steel if it was ductile, or restoring it if lost.

Quenching in a cold liquid is not essential for tempering : a surface tem-

per hardening results whenever rapid cooling by any method occurs after the surface has been heated above 850° C. (1 562° F.). A few examples may be given.

The Wikers surface hardening process is used to harden the surface of the teeth of gear wheels, the heads of rails in place, axles, etc. : it consists in heating by the oxy-acetylene flame the surface to be hardened, and cooling it off immediately by a jet of cold water.

When treated by the Sandberg process, the face of the rail head is cooled by playing a powerful jet of water on to it as it leaves the rolls.

In 1912 Professor Tchernoff (*Revue de Métallurgie*, October 1915) reported an instance of superficial heat hardening : the inside of a gun tube hardens and becomes covered with fine hair cracks in appearance much as on the test piece (fig. 5). Tchernoff explained the case as one of automatic heat hardening caused by instantaneous surface heating followed by cooling by conduction to the underlying metal which had not had time to heat up. He suggested as a remedy lower gas temperatures by an alteration in composition of the explosive used.

The surface of the rolls, made of semi-steel, of a quality that can be hardened easily, used at a Steel Works in Lorraine was hardened by heating very quickly one after the other the projecting rings with an oxy-acetylene flame. The cooling was assured by the interior mass of metal. The hardened surfaces became covered with parallel cracks as shewn in figure 9. The wear of cylinders treated in this way was much reduced and they were not weakened in any way. This example should be remembered as the work done by the rolls in a mill is in many ways like that done by the rails : each point of the surface is in turn in tension and compression : the speed of reversal of stress is of the same order in each case : finally the roll takes hold of a bar in just the way a wheel coming on to a rail results in a suddenly applied load which is, however, very different from a real blow.

A method of cutting up round bars into shell blanks by heating a point of the bar very quickly with the oxy-acetylene flame, and then breaking the bar by a blow from a tup of moderate weight on the other side was much used in France towards the end of the War. The point hardened opened under the blow and formed an incipient crack which acted as a starting point for fracture just as pre-existent cracks always do. Heavy rails may also be cut to length by the automatic hardening of a small spot on the head.

This method of cutting up is affected by the temperature in summer : the bars have to be cooled off with water during the day and broken during the night. This observed fact is in agreement with the greater frequency of broken rails noted in winter. The heat treatment in use at the Steel Works of Neuves-Maisons (*Revue de Métallurgie*, February 1926) is to harden the whole of the top of the rail head after the rail has left the rolls by several successive quenchings in cold water, the heat being allowed to rise by conduction between each quenching. The hardening so obtained is quite different from superficial automatic hardening as it is deep and graduated, and is obtained by using an external cooling agent.

The whole of the conditions necessary to cause automatic heat hardening of the surface of a rail are to be found when the rail is submitted to the friction of a locomotive driving wheel slipping *when about to start*. The violence of the slip that occurs, affecting only a few square centimetres, develops great heat which increases in quantity and temperature with the weight on the wheel, its tangential velocity, and the

time the slip lasts. The progressive heating of the metal by raising the coefficient of friction further adds to the work absorbed.

That the temperature increases to well above 850° C. (1 562° F.) is definitely proved by the metal being cut out of the top of rails by continued slipping to such an extent as to make it necessary to remove the rail, although such cases rarely occur. A recent example may be quoted. On the 7 August 1925 a Paris Orléans Railway suburban train, worked by two electric motor coaches with distant control, one at the head and one at the rear of the train, was stopped by the brakes in the station at Ivry-sur-Seine. Owing to a defect in the automatic distant control gear, the driving wheels of the rear locomotive continued to rotate until the electrician got to it and cut off current. Each of the four wheels of the motor bogie hollowed out a rail to a depth of 9 mm. (11/32 inch) for a length of 190 mm. (7 7/16 inches) with very large flashes all round. Similar incidents have occurred on the electrified line from Les Invalides to Versailles and on the Paris Metropolitain.

The surface of such flats is not found to be hardened when Brinell tested. Heat hardening has not taken place because the heat produced by the prolonged slipping has had time to affect the *whole head,* thereby suppressing the reserve of cold required for hardening.

To get hardening after a slip, the local heating must exceed 850° C. (1 562° F.) and be of short duration so as to leave the surrounding metal cold.

The print (fig. 1) reproduces the work of a single slip which illustrates the point very well. The length of the skid and the flashes round the black oval area in the centre indicate a temperature exceeding 850° C.; the bright ring round it delimits the hardened area so exactly as to be inexplicable except as a result of heating to a critical temperature. Nothing like it can be seen round a work hardened area.

The temperature required to soften the metal in this way would be more than high enough to destroy by reheating the work hardened part if formed at the beginning of the slip.

The preceding remarks explain why an axle loaded to 10 tons is less likely to cause automatic heat hardening than one loaded to 20 tons : the time taken to heat up to the critical temperature is longer, the cooling off is not so sudden and the hardening not so marked.

They also explain why wheel slips on curves have more effect on the lower rail than on the other : when the engine is not moving forward the inclination throws more weight on to the former than on to the second.

The curve (fig. 13) shews the distribution of weight on the rails in relation to the super-elevation for two old or two new engines of the Orléans System.

With new engines the difference due to the super-elevation when standing increases as the loads and as the centre of gravity are raised. The curve shews that when the super-elevation is high the weight of a new engine on the upper rail is comparable to that of an old engine on the lower. The increase of heavy engines favours the production of automatic heat hardening by slipping on condition, of course, that the engines compared are handling loads proportional to their power.

Everything above refers to a slip *in place when starting* : quite different is the « *skid slipping* » of the driving wheels at slow speed which generally causes work hardening, and of which more will be said later. Both these two types of skid are found mixed together near some ash pits at which starting is very difficult. It is probable that the Grisolles rail, which was in such a posi-

tion, was both work hardened and automatic heat hardened.

Work Hardening. — Superficial work hardening of the steel is produced by all mechanical action, which produces fine grain, such as hammering, rolling, drawing, or extruding. It is found in all classes of steels used for rail making. It is done when cold, or at low temperatures : heating to 800° C. (1 472° F.) destroys it.

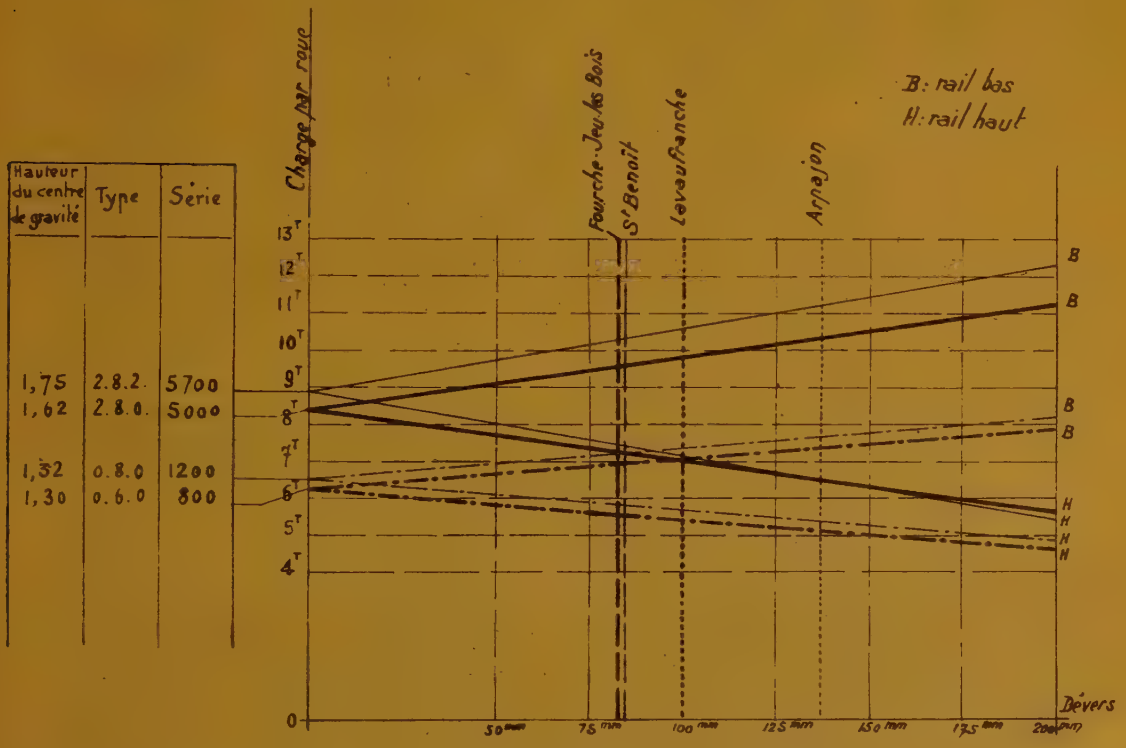


Fig. 13.

Explanation of French terms : Hauteur du centre de gravité = Height of centre of gravity. — Charge par roue = Weight per wheel. B : rail bas = Lower rail. — H : rail haut = Upper rail. — Dévers = Super-elevation.

The effect of work hardening is essentially progressive, penetrating from the outside inwards without sudden changes, completely different from that of superficial hardening by heating. The different structures, according to the cause of the hardening, cold work or heat hardening, in the immediately underlying metal, assist the cracks on the surface of a hard patch on a rail to develop inwards. This is undoubtedly the explanation why cracks from cold work hardening have less serious consequence than those due to automatic heat hardening.

What are the conditions in which a passing wheel can cause cold work hardening? There are three cases to

consider : wheel running free : wheel braked : driving wheels slipping whilst engine is in motion.

Free wheel. — The rolling action of a free wheel usually does not produce any cold work hardened effect, or at most to an inappreciable extent. Rails much cold work hardened wear quickly: on the Orléans System more than 75 % of the rails removed shew a wear much greater than that of those cold work hardened.

Some interesting information was got from the Tulle to Clermont line which is double track betwen Volvic and Clermont (fig. 14). The trace of the line is much the same between Durtol and Royat as between Royat and Clermont — the line on an almost continuous gradient of 25 mm. (1 in 40) is full of curves, many of 250 m. (12 1/2 chains) radius. The traffic is the same in the two sections.. The rails are all of the same make and age. On the second section many cold work hardened and cracked rails are found on down and on up gradients, whereas very few are found in the first. Later on the operating conditions which are responsible for the unusual cold work hardening of rails between Royat and Clermont will be described : they are not found to any extent between Durtol and Royat. On the latter section the differential friction of the free wheels that occurs on sharp curves has not been followed by any appreciable superficial cold work hardening.

On curves of 300 m. (15 chains) or less run through at high speed, the inside edge of the upper rail is very quickly chamfered off. Brinell tests shew that the chamfer with its rough edges is not cold work hardened, although the abnormal wear is caused by friction due to slipping. The flange undoubtedly acts on the rail like a tool which planes it away without hardening it.

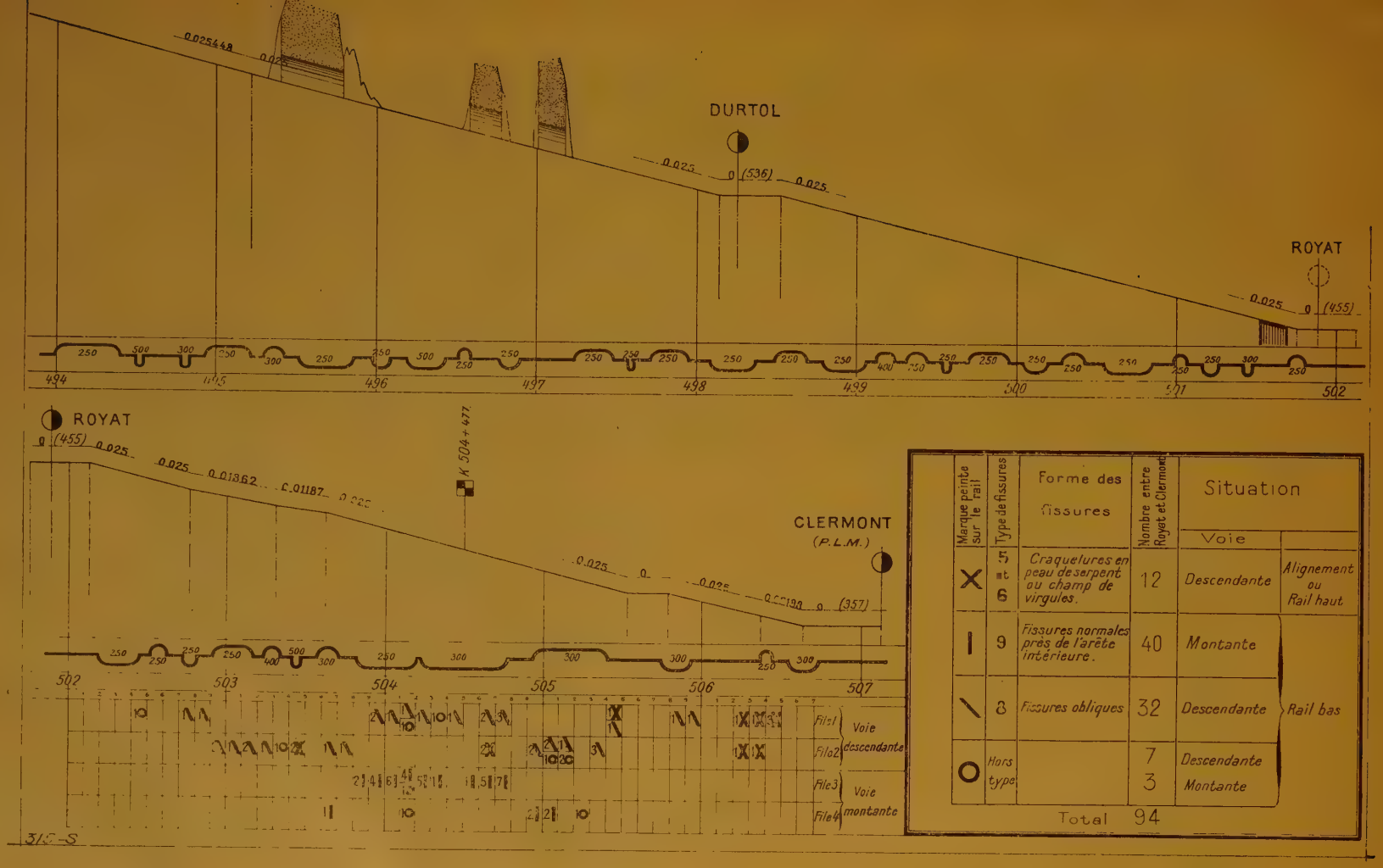
Breaked wheel. — With few exceptions, the continuous brake is applied with a leverage low enough to ensure that the wheels do not skid even when the vehicle is empty. It has therefore little effect on the rolling friction on the rail. This explains why cold work hardening is not noticed to any extent at places where fast trains stop.

It is not at all the same when the wheel is handbraked and is skidded and slides on the rail. Several cases of skidding will now be looked into. The most frequent is that of ordinary goods wagons empty or lightly loaded with the hand brake applied too hard. The skidding does not necessarily take place at once : it may occur after a short delay because the co-efficient of friction of the brake shoes on the wheel increases as the speed diminishes.

The permanent way staff frequently notice that the wheels of the empty leading brake and of *twin* brakes are picked up when descending steep gradients. When two braked wagons are coupled together, in many instances one is loaded and the other is empty. The brakesman travels for preference in the former as it rides better, and does not fully appreciate the extent to which the empty wagon is braked, when he applies the brake in response to the driver's urgent signal.

The old goods tender engines have only recently been fitted with the continuous brake. Before this was done the tender wheels, with the weights often incorrectly adjusted, frequently picked up as shewn by the number of flats on their tyres. Another, but infrequent, cause of the driving wheels of a locomotive skidding is the use of the counter-steam in addition to the brake. This kind of slip is much more serious because the forces brought into action are much greater.

Sliding slip. — The friction on the



Marque peinte sur le rail	Type de fissures	Forme des fissures	Nombre entre Royat et Clermont	Situation	
				Voie	
X	5 et 6	Craquelures en peau de serpent ou champ de virgules.	12	Descendante	Alignement ou Rail haut
I	9	Fissures normales près de l'arête intérieure.	40	Montante	Rail bas
/	8	Fissures obliques	32	Descendante	
O	Hors type		7	Descendante	
			3	Montante	
		Total	94		

Fig. 14. — Section of the line from Tulle to Clermont, near Clermont, shewing the position of cracked rails found between Royat and Clermont (April 1926).

Explanation of French terms : Alignement ou rail haut = Straight or upper rail. — Craquelures en peau de serpent ou champ de virgules = Hair cracks like a snake skin or innumerable commas. — Descendante = Down gradient. — Fissures normales près de l'arête intérieure = Normal fine cracks near the inner edge of the rail. — Fissures obliques = Oblique fine cracks. — Forme des fissures = Form of fine cracks. — Hors type = Of undefined type. — Marque peinte sur le rail = Mark painted on the rail. — Montante = Rising gradient. — Nombre entre Royat et Clermont = Number between Royat and Clermont. — Rail bas = Lower rail. — Type de fissures = Type of fine cracks. — Voie = Track.

rail with a *sliding slip* of the driving wheels of a locomotive is much greater and can occur in at least three ways :

1. After starting from a difficult place whilst the train is running at very slow speed the engine sometimes slips, without the train stopping, during the first few revolutions of the wheels. This kind of skid is frequent at places such as Blois and Saint-Sulpice-Laurière, which will be mentioned later. The marks are mixed up with those due to single slips before the engine moves forward;

2. When an engine is hauling a train rather too heavy for its power on a line with many curves on a steep gradient, it works badly, and without the train stopping, the driving wheels slip and slide, either because the train resistance increases as, for example, when running through a sharp curve, or because the adhesion falls off, as on a greasy rail, or a rail covered with leaves or frost, or in a wet tunnel;

3. When running down a steep gradient the driver waits too long before making use of counter-steam, and then over-does it, making the wheels slip *backwards*, whilst the engine continues to slide forward. Sliding slips, particularly such as the last, obviously try the surface of the rail much more than a skidded wheel. The rail, in neither the one nor the other case, however, as the point of contact changes, is not heated anywhere up to the hardening temperature. Except in rare instances, such slips do not produce work hardening.

TESTS OF RAILS AUTOMATIC HEAT OR COLD WORK HARDENED. — 1. *Laboratory tests.* — At the beginning of the note the information collected by the experts on the pieces of broken rail from Grisolles was noted. The pieces under bend test supported either a very great or a very small load, depending upon whether the hardened layer of the rail on the test piece was in compression or in tension.

When the bend tests are replaced by shock tests the same results were obtained on automatic heat hardened or cold work hardened rails *whether they were cracked or not before the test.* As was noted when the method of sectioning shell bars by a simple point superficially heat hardened was described, the crack which started in the hard layer under tension by bending or, above all, by a blow, can cause the total fracture just as well as an old crack.

None the less, there are many cold work hardened rails in the tracks, some with these cracks and some without, which would break if, after *turning over,* they were slightly bent or given a light blow, but which in use do not break unless they are segregated or piped sufficiently for these defects by themselves to cause a fracture.

The brittleness ascribable to the presence of a hard superficial layer is therefore of a very special nature, and entirely different from the general brittleness of the whole rail. It is certainly advisable to require a drop test when inspecting rails in order to reveal defects in manufacture. But the following observed fact must be admitted : a rail that was not brittle before being put in place, and in which in service brittleness due to the cold work hardening of the surface develops, behaves in use as if it had remained sound. *Cold work hardening,* and not *automatic heat hardening* is mentioned, as the many accidents, some of them serious, can only be explained by the breaking of heat hardened rails.

In future, when making laboratory tests of rails hardened superficially, the shock test will be replaced by a bend test, using a variable speed press, the deflection and the load as a function of the time being observed. In this way the conditions met in practice can be best reproduced.

Without endeavouring to group to-

gether widely different phenomena, it should be remembered that paving stones in hard granite, are dressed by chipping simply by a blow of a heavy hammer whereas when in place in a road they stand very much greater shocks (*Revue de Métallurgie*, September 1907, Mr. de Fréminville).

Mr. Chagnoux in 1913 demonstrated that a mild steel test piece, cold work hardened by hammering one of its faces, revealed the characteristic brittleness of superficially hardened rails. Mr. Chagnoux recently repeated these tests on test pieces cut from the heads of rails of different quality steels. For each quality he made comparative tests between superficial hardening due to cold working, and heat hardening by the Wikers method. He will publish the results of these tests in a special report at a later date.

2. *Tests of rails in place in the track.* — In 1921 a simple method of comparing the resistance to slipping of rails of different qualities was devised. The engine hauling a heavy train or a number of wagons with the brakes applied was made to slip by greasing the rails on a straight section. The rails to be compared were placed opposite one another so that the same slip affected both. At that time the investigation of automatic heat hardening alone was under consideration. The first test of this kind was made in 1924 in the marshalling yard at Juvisy. The tests were not continued because in 1925 the Neuves-Maisons Steel Company put in hand a more extended and most methodical application of the method on a track in the works so as to obtain quickly information of the relative tendency of rails of various qualities, either previously heat treated, or not, to develop these fine cracks.

The rails to be tested are subjected to sliding slips of an engine moving slowly enough to give rise to a slight heat hardening. The fragility of the rail is then measured under shock. In a recent note (*Revue de Métallurgie*, February 1926) Mr. Thibaudier and Mr. Viteaux, Directors of the Neuves-Maisons Steel Company, say the results will be published at a later date. It may be said even now, however, that their tests, like those made by us, shew beyond dispute that the special brittleness caused by superficial hardening occurs in sound rails as in those segregated or piped.

Another method of comparison which takes more time, but more closely repeats practical conditions, is to lay the different rails to be compared one after another at a place from which trains start, such as the yards at Blois or Saint-Sulpice-Laurière, where slipping is exceptionally frequent and where every type of slip is found.

IV. — Facts noted and investigation into causes thereof.

The accidents or incidents, attributable on the Orléans system to the fracture of rails become brittle by the hardening of the surface, all occurred at places where slipping whilst standing is frequent. There is no record of a single accident which could be ascribed to cold work hardening of the rail alone. When the records are being considered cases of automatic heat hardening should be distinguished from those of cold work hardening.

Cases of automatic heat hardening. — *a*) *Starting.* — 1. Blois station. — On the 27 February 1914, when the express train No. 19 was starting out of Blois station, three coaches derailed on a rail which broke into nine pieces near the ashpit on the main down line. The rail was on the lower side of a curve of 600 m. (30 chains) radius with a superelevation of 0.16 m. (6 5/16 inches) to

suit the fast trains which run through without slowing down. The rail, of pattern D.C. unsymmetrical of 43 kgr. (86.7 lb. per yard), was manufactured in 1895 of 70 kgr. (44.5 tons) steel. It was only worn 1.5 mm. (1/16 inch) and was marked by many slips and shewed many hair cracks. The adjoining rails for a length of 50 m. (164 feet) had the same appearance, although those on the high side were less affected. The frequent slipping at this place is explained by the usual heavy loads of the trains and by the curve with the high super-elevation of the outer rail. The distance over which slipping occurs is because most of the engines neither take water at Blois nor stop over the pit. A count over seven consecutive days in July 1925 shewed that at this place on each line of rail an average of 40 slips per day occurred.

2. Saint-Sulpice-Laurière Station. — The same condition as at Blois : most of the trains from Paris to Toulouse stop and slip at starting on a curve of 700 m. (35 chains) radius with 0.10 m. (3 15/16 inches) super-elevation. The super-elevation is considerable because some express trains run through without stopping or even reducing speed. The place where slipping occurs is however shorter, as all trains stopping take water at the pit. The number of slips noted in the same time as at Blois amounted to 44 per day. There have been no derailments. The line is kept under special supervision and the rails on which slipping has occurred are replaced after a few months' use.

3. Austerlitz Station. — Slipping occurs at two stopping places on the down line. Trains from Orsay are sometimes stopped on a curve of 300 m. (15 chains) radius and a rising gradient of 11 mm. (1 in 91) at the end of the platforms, and slip when restarting. When leaving Austerlitz, the engine, being on a sharp curve and on rails often greasy, frequently slips.

4. Brive Station. — Up goods trains stop on two fast roads in the main station before drawing forward into the marshalling yard. Although the engine and train are on a straight level line, the rails just before the signal are covered with marks of slips due to oil dropped by the engines during the time they are standing.

b) Starting after a stop on open lines. — 5. Saint-Sulpice-Laurière to Montluçon near Saint-Sulpice. — On the 24 February 1924 a goods train from Saint-Sulpice came off the line 330 m. (1 083 feet) from the junction on a rail broken into nine pieces.

The broken rail, type D. C. symmetrical, 38 kgr. (76.6 lb.) shewed marks of many slips, as did the nearby rails : the rail was on the lower side of a curve of 300 m. (15 chains) radius, super-elevation 0.098 m. (3 13/16 inches), ascending gradient of 12 mm. (1 in 83), the steepest on the line.

The points of the junction are in the station itself, and immediately beyond them the trains come on to the curve of 300 m. (15 chains) and the rising gradient of 12 mm. (1 in 83).

In winter the goods trains are cold when leaving Saint-Sulpice where they are formed. The increased resistance resulting, added to that of the gradient, overloads the engine at the place where it is exerting its maximum effort, especially when the rail is slippery through frost or fog. The same train when out of this section clears without difficulty other sections with similar gradients because the axle boxes have had time to warm up.

6. Brive to Capdenac near Brive. — The conditions are the same at Brive for the slow goods trains which have to start whilst dead cold over a rising gra-

dient full of curves towards Capdenac.

7. Clermont to Tulle near Clermont. — Similar conditions at Clermont for slow speed trains starting towards Tulle.

8. Saint-Sulpice-Laurière to Montluçon near Lavaud-Franche. — Trains from Montluçon on the single line approach the junction of Lavaud-Franche by a rising gradient of 12.5 mm. (1 in 80) on a curve of 300 m. (15 chains), the maximum of the section. These trains stop short of the points into the station when crossing another train, or if they have to be shunted on to another track. In practice almost all the trains stop and have to start on a curve and a rising gradient. For a length of 30 m. (98 ft. 5 in.) before the points are reached many slips had occurred on the rails during an exceptional period when engines rather small for the loads to be hauled had to be used. Between July 1921 and April 1923, five rails of the lower side broke, but no derailments occurred. The use of more powerful engines stopped the slipping and the breakages.

c) *Shunting.* — 9. Saint-Benoît. — On the 25 March 1925 the fast express train No. 34, from Bordeaux to Paris, came off the line on a rail broken into 21 pieces just after passing the junction of Saint-Benoît near Poitiers.

The rail D. C. of 42 kgr. (84.7 lb.) dissymmetrical of 70 kgr. (44.5 English tons per square inch) quality was made in 1895. It had been much slipped on and shewed many fine cracks, like the neighbouring rails, for a length of about 200 m. (656 feet).

The rail was the lower rail on a curve of 1 000 m. (50 chains) radius on a down gradient of 5 mm. (1 in 200) with a super-elevation of 0.085 m. (3 5/16 inches). The derailment caused four other rails on which there had been slipping to break, two on each side.

A few years ago, an additional group of holding sidings was put down at Saint-Benoît to deal with up goods trains when the yard at Poitiers is blocked. The trains were set back into these sidings on the up road up a gradient round a curve, and through many points and crossings. The high resistance resulting from these conditions explains the frequent slipping.

10. Arpajon Station. — The express train No. 103 from Paris to Nantes by Châteaudun on the 23 May 1921 came off the line on a rail broken into 8 pieces when leaving Arpajon station, near Brétigny, through which it had passed without stopping. This rail was of the D. C. type 38 kgr. (76.6 lb. per yard dissymmetrical, of 70 kgr. (44.5 English tons per square inch) — close in type Martin steel made in 1901. The metal was perfectly sound. The rail was on the lower side of a curve of 480 m. (24 chains) with a super-elevation of 0.14 m. (5 1/2 inches) and a down gradient of 8 mm. (1 in 125), the maximum of the section.

The surface shewed many slips and was covered with fine cracks (fig. 3), like the others adjacent to it because goods trains picking up wagons in the station slipped when pushing the wagons through a curve on an up gradient.

11. Fourche-Jeu-les-Bois. — On the 31 March 1925 a goods train came off the line on a rail broken into six pieces near the halt at Fourche-Jeu-les-Bois on the single line from Châteauroux to Montluçon.

The broken rail was of the D. C. symmetrical type of 38 kgr. (76.6 lb. per yard) of 70 kgr. (44.5 English tons per square inch) quality made in 1879 of Martin steel. The wear was 4.4 mm. (11/64 in.). It bore marks of slips and had fine cracks, like neighbouring rails, for a length of 100 m. (328 feet) about.

The rail was on the lower side of a curve of 600 m. (30 chains), super-elevation of 0.08 m. (3 5/32 inches) on a

rising gradient of 8 mm. (1 in 125) where slipping is frequent when up passenger trains start after stopping at Fourche.

12. Shunting necks in the marshalling yards at Les Aubrais and Vierzon. — On the shunting necks for the south hump of the two marshalling yards at Les Aubrais and Vierzon on a heavy up gradient, many failures of rails on which there has been slipping, and which are covered with fine cracks, have occurred when engines too light for the weight of the trains are used for shunting. When heavier engines were used, the failures of rails ceased.

Cold work hardening. — 13. Section between Royat and Clermont-Ferrand. — The 20 km. (12 1/2 miles) section from Volvic to Clermont is common to both the Tulle and Saint-Eloi to Clermont lines. It was double tracked in 1909 when new D. C. dissymmetrical rails of 38 kgr. (76.6 lb. per yard) were used.

About 19 trains a day run over each line, 10 of them goods. Both slow and fast goods trains are worked by *Mikado* tender engines with 17 1/2 t. on the coupled wheels. Between Durtol and Clermont the line falls, the maximum gradient being 25 mm. (1 in 40) almost continuously, the only level stretches being in stations. There are very many curves, almost all of the minimum radius of 250 m. (12 1/2 chains). Both the layout of the line and the trains concerned are the same between Royat and Clermont. 94 rails were found shewing pronounced fine cracks caused by cold work hardening, whereas an insignificant number only, and with very slight cracks, were observed between Durtol and Royat.

All causes producing cold work hardening were found on the first section, whereas most of them were wanting on the second. Slow speed goods trains descending the bank have to stop at the outer home signal at Clermont. This signal is fitted with detonator placers, and is right on the down gradient of 25 mm. (1 in 40) at the middle of a curve of the unusual developed length of 972 m. (3 188 feet). It is so difficult to stop at this point that the fog signals are detonated on an average once a day. This difficulty results in the wagon wheels being skidded and the coupled wheels being locked by the additional application of the air brake, and by the use of counter-steam. The result is the crushing of the lower rail of the curve and the formation of the kind of oblique hair cracks shewn in figure 8. On the same track at the top of the bank near Royat, the same hair cracks and crushing of the rail without cracks, as shewn in figure 7, are noticed on the lower rail at the point where the drivers use the counter-steam which, if carelessly applied, wil cause the wheels to slip.

On the same track in a very wet cutting just before reaching Clermont station, fine hair cracks of the type shewn in figure 5 are found, both on the upper rails on the curve, and on the straight, caused by picked up wheels. On the up gradient all the fine cracks are of the type shewn in figure 9. They are all on the lower rails of the first curves encountered on which the engines working the slow speed goods trains slip and slide when starting dead cold trains or in frosty weather.

This section is very instructive, as owing to the rails being of the same age, to the double lines being in use, and to the local operating conditions, the effects can be readily traced to their causes. The few rails slightly affected found between Durtol and Royat are crushed as shewn in figure 9 and are the lower rails of the up grade curve : they shew that the engines sometimes slide with the wheels picked up.

14. Section from Brive to Montplaisir

(line from Brive to Capdenac). — This single line carries a heavy traffic. When leaving Brive the trains marshalled at this point have a long climb up 12.5 mm. (1 in 80), the maximum gradient of the line with many curves of 300 m. (15 chains) in front of them. As explained above, in winter sliding slips are frequent over a length of 650 m. (2 132 feet) and sometimes the engines have difficulty in handling the trains.

The lower rail is found to be crushed with fine cracks as shewn in figure 9. There are also a number of fine hair cracks of the types shewn in figures 5 and 6 caused by trains descending with skidded wheels. The gradient extends much further, but the only work hardened rails found are on this short section at the starting point.

15. Up gradients at Lioran. — The single line from Aurillac to Arvant which crosses the Cantal at the Lioran pass (1 152 m. = 3 780 feet high) has curves of 300 m. (15 chains) minimum radius, maximum gradient of 20 mm. (1 in 50) at the ends of the section, and 30 mm. (1 in 33) near the summit for a length of 28 km. (17 1/2 miles).

At the three intermediate stations there are short lengths on the level. The Paris Orléans regulations require safety stops to be made at passing places before reaching the points, that is to say, on the gradient of 30 mm. (1 in 33) itself. As trains frequently pass one another at the three stations, the trains ascending have to start on the gradient of 1 in 33, and the descending trains stop on it. The result is many slips and skids : there are, however, fewer than on the section between Royat and Clermont on the one hand, because the trains marshalled at Aurillac or at Arvant have travelled some distance before reaching the foot of the incline, and on the other, because the trains worked down the 20 mm. (1 in 50) gradient by one engine are double headed, both up and down the 30 mm. (1 in 33) gradient.

The 28 km. (17 1/2 miles) of steepest gradient are laid in about equal lengths with D. C. rails of three different types :

Symmetrical rails 38.200 kgr. (77 lb. per yard) of various makes and ages, but all made before 1890;

New unsymmetrical rails 38 kgr. (76.6 lb. per yard) laid in 1911;

Unsymmetrical rails 42 kgr. (84.6 lb. per yard) laid in 1911 and 1912 after some considerable previous use in the Paris to Orléans line.

No fine cracks nor hair cracks can be found in the two first lots, whilst two-thirds of the last are more or less cracked, as shewn in figures 5, 6 and 9. A large number of these rails, laid as the upper rail on a curve after having the inner radius chamfered off, has been replaced by rails from straight sections of line. When use on a single line and a long previous use on another line are added to this, the impossibility of sorting out the effects of using the rail at different places, and of the different operating conditions, on the formation of the cracks will be recognised. The question may be asked how the almost general deterioration of the third lot is to be explained, seeing that the other two lots stand up for an almost equal length of service to that at Lioran and under the same operating conditions.

It is possible that the rails of the third lot might have been in use in a section where they had already been cold work hardened, either because of the quality of steel used, or more probably because they had often carried brake skidded wheels of wagons and especially of old tenders.

Since 1912, that is, for the last fourteen years, one single rail only has broken in the track, and this shewed a defect in manufacture.

The fact that 1 144 rails out of 1 708, have remained in use, although shewing

fine cracks and signs of cold work hardening, for several years, probably ever since they were delivered at Lioran, without a single breakage, can only lead to the conclusion : that the brittleness due to cold work hardening with or without fine cracks, is in no way comparable to the usual brittleness, nor to that due to automatic heat hardening.

Furthermore, the presence of three lots of rails at Lioran enabled their respective resistances to wear on curves to be compared : the pear-shaped head of the old symmetrical rail crushes and is chamfered off much less quickly than the square head of the two symmetrical type rails on curves of 300 m. (15 chains) radius.

16. Rail at Pierre-Buffière. — On the 3 January 1911 an express from Brive to Limoges derailed at 200 m. (656 feet) before Pierre-Buffière station through which it should have run without slowing down.

The derailment was caused by a rail breaking under the engine, the rail head being partly broken away for a length of 0.40 m. (15 3/4 inches) along a *segregation* line at the near end of the rail. The defect was hidden by the fishplates. The metal was of normal composition, but the manufacture was defective. This rail D. C. symmetrical 38.200 kgr. (77 lb. per yard), 11 m. (36 ft. 1 in.) long was laid when new at the opening of the line in 1893 : it had therefore been in service 18 years. The wear was very little, 2.4 mm. (3/32 inches). The double track line carries an average traffic.

The rolling surface was covered by a mass of fine hair cracks and fine transverse cracks, as shewn by the print for this rail (fig. 5). The rail was found to be very brittle when drop tested after being turned over. Test bars, cut 3 mm. (1/8 inch) below the rolling surface gave good Charpy tests. The segregation was the cause of the failure : the cold work hardening had only helped the rail to break into several pieces.

The position of the rail was such that only one cause for the cold work hardening could be admitted. The rail was on a curve of 600 m. (30 chains) radius, super-elevation of 0.128 m. (5 1/32 inches) on the higher side, at the foot of a long down gradient of 10 mm. (1 in 100) the steepest on the line, and 50 m. (164 feet) short of the small length of level line in the station. The lines in the station are so arranged that trains do not shunt or start at this point, and there is therefore no slipping. At the foot of the long down gradient, the goods trains have to make full available use of all brake appliances to stop on the short stretch of level in the station. The cold work hardened rail has therefore been passed over by many picked up wheels on wagons or on old tenders.

V. — **Remedies**.

The first remedy that suggests itself is to alter, as far as practicable, those methods of operation which assist the cold work or automatic heat hardening of the rails. For example, a stop at passing places could be replaced by a speed reduction on single lines, or when running into holding sidings.

Continuous brakes on goods trains would obviously improve things as they would do away with the skidding of wheels and mis-use of the counter-steam, that is to say, the two most frequent causes of cold word hardening.

An increase in the adhesive weight of the engines relatively to the weight of the trains hauled would also reduce slipping, whether before or whilst in motion. It would however entail an excessive reduction in the output of the engines without preventing slipping on some sections under certain weather conditions.

It would therefore be possible to

reduce the causes of cold work hardening considerably without altering the material of the rails : it is fortunate that it is so seeing that all qualities of steel for rails, soft, medium and hard, are subject to cold work hardening, and it is not yet known how a steel is to be found which will not be so affected.

The method of overcoming automatic heat hardening still remains.

First of all, rails on which slipping has occurred are more easily seen than those cold work hardened, and the places where they are found are fewer, better known, and more easily delimited.

In exceptional places, of short length, as those noted at Austerlitz, Blois, and Saint-Sulpice-Laurière, the ordinary rail could be supported throughout its length. Neither slipping nor automatic heat hardening would thereby be prevented, but they would be rendered harmless, first by preventing the formation of fine cracks through reducing the effect of the reversal of the stresses, and second by holding the rail together if it should happen to break.

With the ordinary flat bottomed rail laid on sleepers, this support could be made from a U section placed under the base of the rail (fig. 15) which it would strengthen but to which a complete fracture of the rail would not extend.

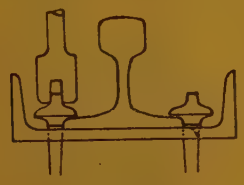


Fig. 15.

On open lines, this solution would not be welcomed owing to the difficulties it would cause in maintenance. In this case a steel that will not harden is required, or, more exactly, a steel that heat treatment would either maintain or improve the ductility. A surface layer heat hardened, having the same co-efficient of extension as the underlying metal, would cause neither cracking nor brittleness.

There is a steel which possesses this property, the ordinary soft steel of 40-45 kgr. (25.4-28.6 English tons per square inch) quality. Heat treatment hardens it very little, and can do nothing but improve its ductility. The very curious effect of heat on mild steel was brought to notice by Mr. Frémont twenty years ago. A quantity of rolled steel angles of 40 kgr. (25.4 English tons per square inch.) quality for a bridge contained some so brittle that when being unloaded they broke : Mr. Frémont found first of all that the metal of the angles was crystallised by a very slow cooling through having remained some time in the centre of a heap that had collected on leaving the rolls at the rolling mill. He then shewed that to remove the brittleness it was only necessary to heat them above 850° C. (1 562° F.) and then quench them in cold water.

The lesson was valuable : several railway Companies at that time prescribed cooling *very slowly* in a furnace for locomotive firebox mild steel plates which had been reheated after forging under a press or hammer. It was realised that the greater tendency to lamination of these plates was due to the slow cooling and a quick cooling in air, called air tempering, was specified.

A large steel works manufactured in mild steel, steam hammer piston rods : the frequent failures experienced when cooled off slowly, after forging and reheating, ceased when they were quenched in cold water.

The quenching in water is out of the question for rails as it deforms and strains them. The graduated and partial hardening obtained by the Neuves-Maisons process applied to mild steel rails might overcome these defects and

give valuable results. The tests shewed this to be so : rails manufactured in this way, after being submitted to slide slips, were free from any brittleness, whilst rails not so treated had become very brittle under the same slipping.

As the resistance to bending of such rails would be much less than that of rails of 70 kgr. (44.5 English tons per square inch) quality, the sleepers would have to be laid closer together to make up for it.

The locomotive used for the first test at Neuves-Maisons had an axle load of 12 t. only : it will be as well to wait the results of a second test to be made shortly using a locomotive with 18 t. axle load. If they are satisfactory, such rails could be laid on the first section on which slipping occurs, such as that at Brive station, where all trains stop. This would shew how mild steel rails treated in this way would stand up, not only against slipping whilst standing, but also how they would resist wear and crushing.

The use of these treated mild steel rails might be admitted for the restricted areas where slipping is frequent. A more complete solution is wanted : at the present time it is thought a steel, low in carbon and with rather more manganese than the rail steel ordinarily used, could be made which, after proper heat treatment, would not be so brittle and would not harden, but would be very tough with a high limit of elasticity.

[621 .132.8 (.43)]

Turbine locomotive for the German State Railways,

By G. J. MELMS,
CONSULTING ENGINEER, PARIS, FRANCE.

Figs. 1 to 8, pp. 533 to 540.

(*Railway Mechanical Engineer.*)

The endeavor to develop the steam locomotive to a high state of efficiency has resulted in the German State Railways placing an order for a second turbine locomotive from I. A. Maffei, Munich, Bavaria, Germany. This locomotive, which was recently delivered, develops 2 500 H. P., and is designed to haul heavy express trains at an average speed of 62 miles per hour and at maximum speed of 78 miles per hour. The general design and construction of this locomotive has been made as far as possible similar to that of the standard reciprocating Pacific type locomotives recently adopted by the German State Railways. The diameter of the driving wheels of the turbine express locomotive is 68.8 inches, which is about 10 inches less than that of the standard locomotives.

Following the same general trend in the design of the standard locomotives, the construction of all parts of the new turbine locomotive is of the greatest simplicity and they are easy of access. The total weight of this locomotive is 229 000 lb., of which 132 000 lb. is carried on the drivers. The boiler is of conical construction and operates at a pressure of 324 lb.

The turbine and the electric locomo-

Fig. 1. — Turbine locomotive built for the German State Railways by I. A. Maffei, Munich, Bavaria, Germany.

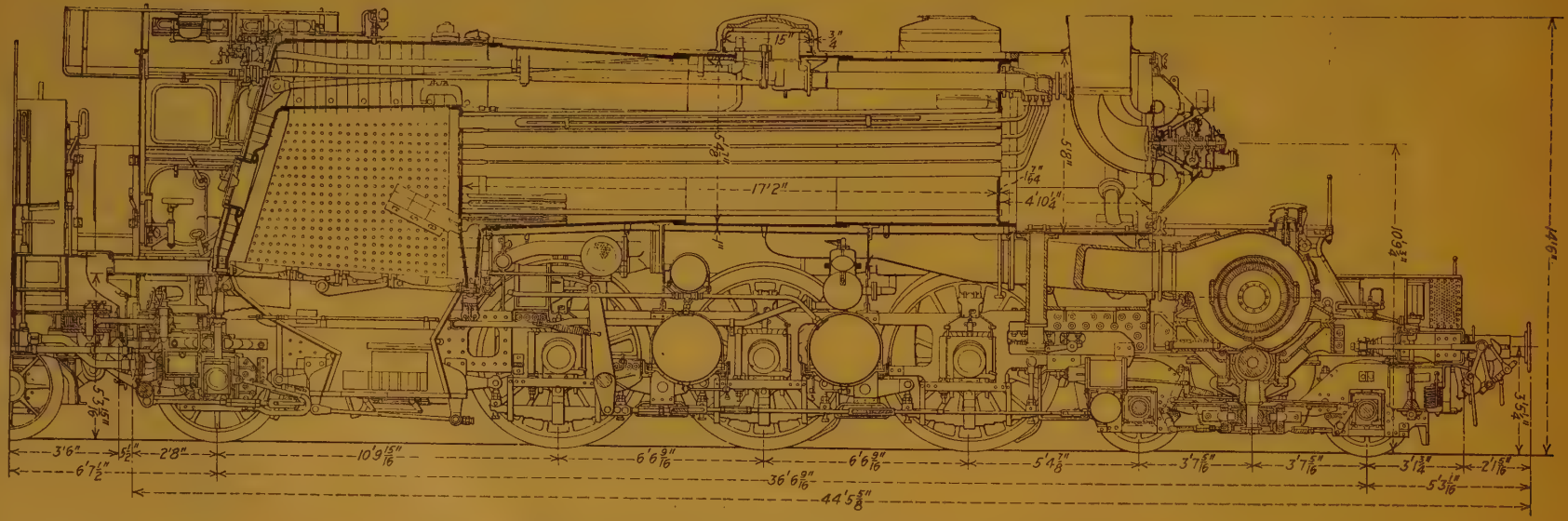


Fig. 2. — Elevation drawing of the German State Railways' turbine locomotive.

tive naturally have many features in common, one of the most important being a smooth starting tractive force. Having a higher adhesion, a greater proportionate tractive force can be utilized than is possible with a reciprocating type locomotive and besides the reciprocating and other parts can be dispensed with.

The greater axle loads permit an increase in the total weight of the locomotive, which made it possible for the builders to increase the boiler pressure to 324 lb. Because of the high pressure and the saving of steam by the condenser, the dimensions of the normal locomotive boiler were considerably reduced. Shortening the boiler length and reducing the smoke box dimensions created additional space on the front end of the locomotive, making room for the turbine and the reduction gearing.

Similar to the electric locomotive, the turbine gear drive is so arranged that the power of the turbine shaft is transmitted by two pinions through reduction gearing to a jack shaft and from this shaft to the main connecting rods and the six-coupled driving wheels.

General description of the Maffei locomotive.

Two surface condensers are located on each side of the boiler. The exhaust piping to these condensers passes through the center supporting yoke of the boiler. A suction draft fan, directly connected to a small turbine, is fixed to the inner side of the smoke box door, and serves to eject the waste gases. The air of the condenser is removed by two single-stage air suction steam ejectors. The condensate water is removed by a pump directly connected to a piston feedwater pump. A Westinghouse air compressor and small turbine-driven dynamo for electric lighting, etc., are also provided.

The tender has been considerably increased over the standard length, the forward part having storage space for fuel and feedwater. Adjoining this is a small space for the turbine which drives the air fans and the cooling water pump. The remaining portion is occupied by the cooling installation, which consists essentially of a spray cooler. The water flows downward over flat metal sheets while the cool air is admitted through the sides of the tender and passes over the flat metal surfaces exposed to the spray, finally being ejected by two fans placed horizontally in the roof of the tender.

The turbine locomotive, considered alone according to the figures comparing it with the standard Pacific type, is the lighter of the two, so the weight of the condensing apparatus results in less weight than that of a standard locomotive.

Comparative weights of the turbine and standard Pacific type locomotives of the German State Railways :

Weights in working order :	Turbine locomotive.	Standard Pacific type locomotive.
On drivers	132 000 lb.	132 800 lb.
Total engine	229 000 lb.	249 000 lb.
Total tender	150 000 lb.	148 000 lb.
Total engine and tender	379 000 lb.	397 000 lb.

It is evident that the cost price of the turbine locomotive will be higher than the reciprocating locomotive, but the latter has the advantage of a century of experience in production which can only be overcome as turbine locomotives increase in number. Of the coal consumed, 15.6 % of the total heat can be

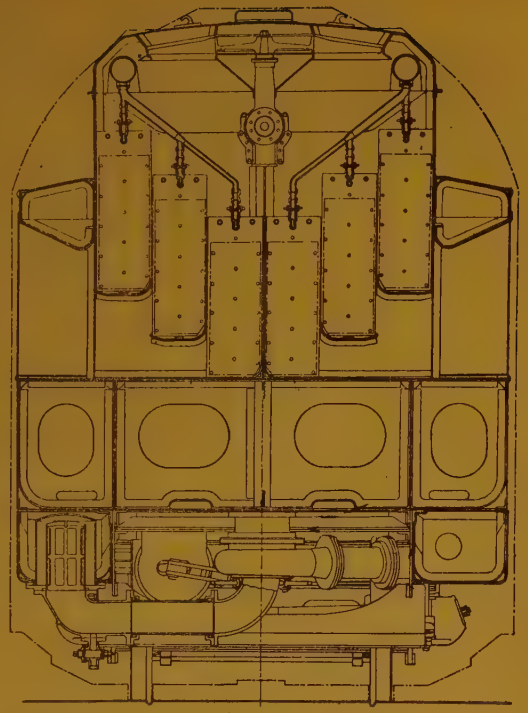


Fig. 3. — End elevation of the tender showing the water cooling units.

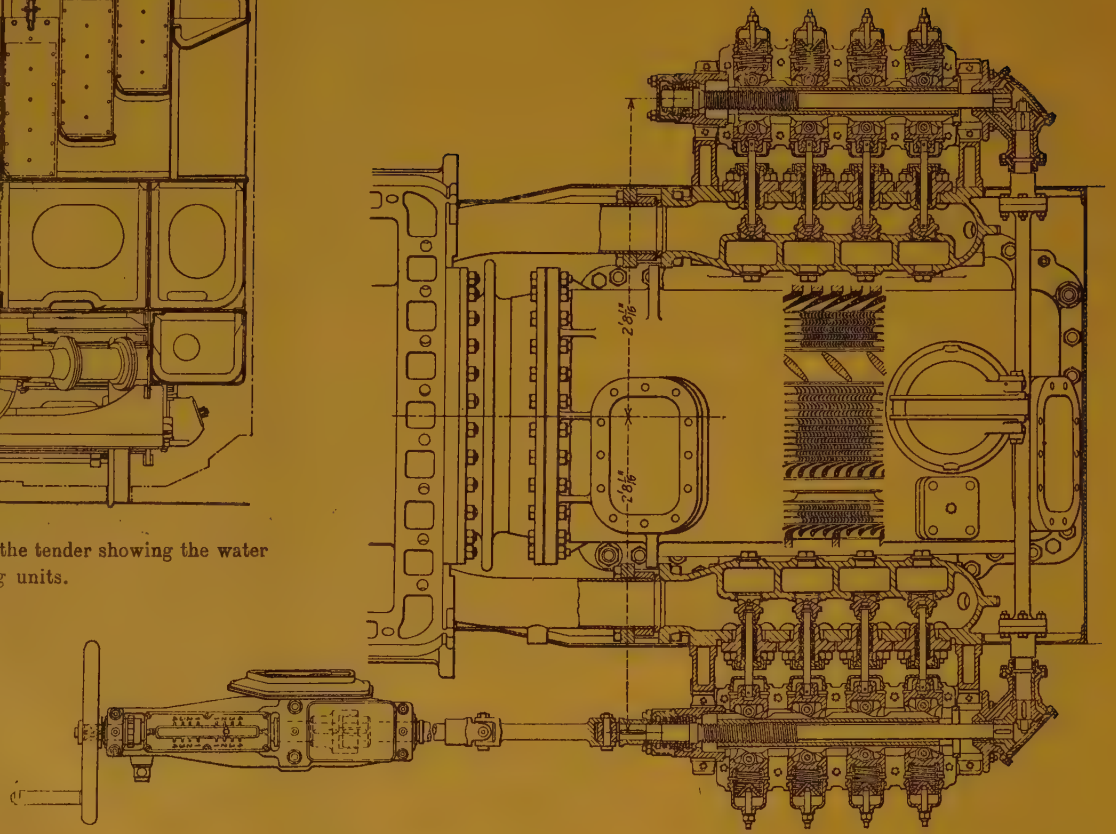


Fig. 4. — Drawing showing the blade arrangement of the main turbine and method of controlling steam distribution.

utilized at the crank pins when the locomotive runs at the rate of 43.5 miles per hour, whereas the express reciprocating type locomotive of standard construction will give a value of 7 to 8 %.

It has been estimated that one H.P. at the jack shaft will absorb 7 280 British thermal units, or with coal having 12-780 British thermal units, 1.26 lb. of coal per H.P. (including the steam used for the auxiliary machinery). In the winter, the total net efficiency will be increased, due to the train heating, and it is then expected to increase up to 20 or 22 %.

The feedwater of the turbine locomotive is forced through two feedwater heaters placed in series, and is heated by the exhaust steam from the auxiliary machines up to a temperature of about 260° F. It must be admitted that by preheating the air for combustion, or by increasing the feedwater heating installation, further saving can be obtained. For example, an increase in the feedwater temperature up to 570° F. and above, by means of the exhaust gases, would also require an increase of the heating surface of the feedwater heater. Cooling the exhaust gases would diminish the volume of the gases and permit the installation of a smaller exhaust fan, which would reduce the amount of work at this point. A saving of 4 % could thus be obtained, but at the cost of considerable complications.

The main turbine and reduction gear.

The turbine is situated above the engine truck with its axis at right angles with the center line of the locomotive and transmits its power by means of a double reduction gear through connecting rods to the driving wheels. The forward drive and the backward drive turbines, are enclosed in the same housing. At a locomotive speed of 78 miles per hour the turbine shaft runs at 8 800 revolutions per minute, which is reduced through a gear ratio of 1 to 24.

The forward turbine consists of two discs in the high pressure end, each containing one row of blades at the rim, followed by an impulse wheel and five reaction wheels of suitable diameters. The end thrust is counter-balanced by a balance piston at the high pressure end.

The backward drive turbine consists of a velocity disc of smaller diameter having three rows of blades revolving in a vacuum while the forward drive turbine is in action. The steam expands in the nozzles of the backward drive turbine from admission to vacuum and exerts but little reaction effect on the blading. The housing of the backward drive turbine is located inside of the main turbine and its construction provides a guide channel so arranged that the exhaust from both turbines is led to the same outlet without interfering; that is, it prevents the steam from one from entering the blading of the other. It is evident that the backward drive turbine cannot produce the same effect as the forward, but this is a secondary question for an express locomotive.

Referring to the drawing showing a section through the main turbine, a separate cast steel steam admission chamber for each turbine is secured to the upper part of the turbine casing. Inasmuch as the backward turbine absorbs the total drop of heat, the nozzles operate with total admission. For that reason the steam admission passages in the casing leading to the nozzles have been made larger than the customary design.

The ends of the shafts of the turbine spindle, referring to the section drawing of the main turbine, are provided with dummy packing which permits the necessary end play. The exhaust flange located on the upper half of the turbine casing, shown in the drawing of the blade arrangement, is coupled to a flexible expansion joint which, in turn, is attached to the boiler support. This

support is so arranged as to serve as a continuation of the vacuum pipe and is divided into two branch pipes under the boiler in order to permit the steam to flow to both of the surface condensers located on both sides of the boiler, as shown in the cross-section drawing, through the smoke-box.

In case the condensers should fail to function, a safety valve prevents any undue pressure on the turbine vacuum pipe line and in the condensers. The safety valve will come into action if the cooling apparatus fails to operate, whereas in case of an accident to the condensate pump, the steam will continue to be condensed and the condensate in by-passing the condensate pump, will then be forced into the feedwater reservoir on account of the high pressure. In this case, the steam injectors can be placed in service.

Construction of the main turbine blades.

The turbine blades are milled out of the solid nickel steel and are machined in special jigs to insure absolute accuracy. The shape of the socket of the blades is made somewhat in the shape of a distorted parallelogram, so that the blades can be inserted in the rim of the disc by a turning motion of the blade. This design eliminates the need of enlarging the groove in the disc and also provides a secure attachment of the blades to the rim. Notches on both sides of the blade fit into a suitable projection in the groove of the disc. Blades having the greatest lengths have tapered tips to compensate for the increased stress. The material from which the blades are milled varies from 3 to 5 % nickel steel or chrome-nickel steel, according to the stress the various blades are subjected to. The shroud ring is made of Monel metal. In order to insure good efficiency even at low load, the forward as well as the backward drive turbines are regulated by four single nozzles. The two cast steel admission chambers attached to the two sides of the upper half of the casing have an independent pipe connection to the superheated steam chest. The valves, provided with nickel seats, are self-closing with positive openings and are connected together by means of a regulator shaft and bevel gears. They can be directly manipulated by the reverse gear control in the cab. A dial and pointer indicate the position of the various valves. The gear can be conveniently handled in a manner similar to that used on most steam locomotives in Europe.

The main regulating valve is not balanced, and it can only be opened by means of a small auxiliary valve. The opening of the auxiliary valve causes a rise in pressure behind the seat of the main valve, all the nozzle valves being closed at the same time. With this arrangement the engineman is obliged to use the gear control for pressure reduction, and not the regulating valves.

The turbine shaft is rigidly secured in the bearings and, in addition, the projecting ends are suitably guided. The pinions are secured to the shaft ends on conical stubs, as shown in one of the drawings, and are allowed little play in the direction of rotation. This is because the ends of the turbine shaft, as well as the hollow shaft on which the pinions are mounted, are of flexible construction. The pinions are located in an exact line with the two intermediate gears. The former are subject only to torque stresses. The shafts are not subjected to any bending moment. The two intermediate gears transmit the total force.

It was found to be expedient to provide a certain flexibility in the direction of rotation which would also tend to insure that each gear would take its share of the work. Springs permit the

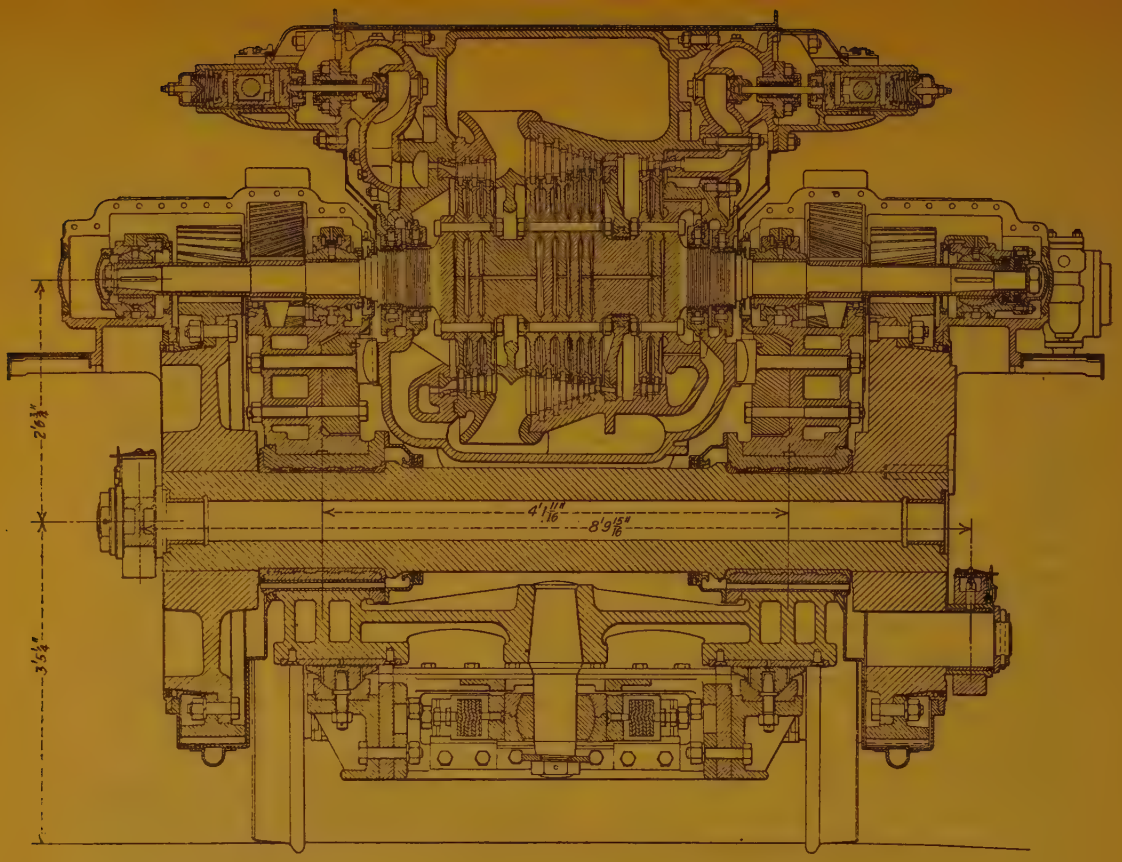


Fig. 5. — Horizontal section through the main turbine.

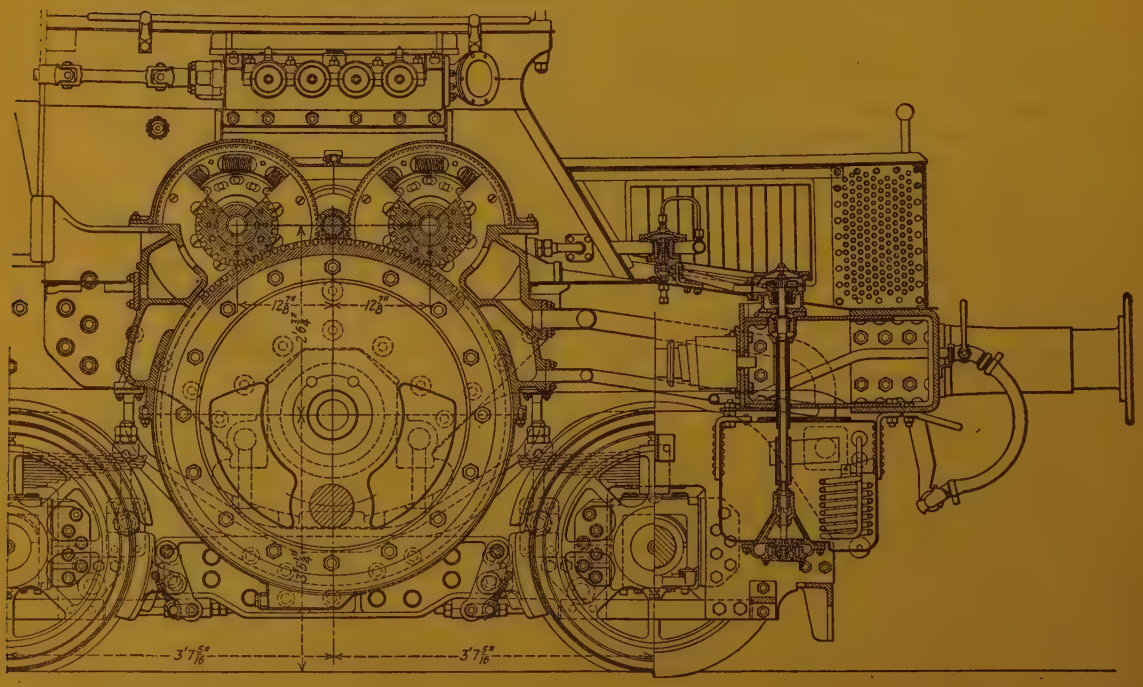


Fig. 6. — Arrangement of reduction gearing from the main turbine.

gear frame to be subjected to considerable play in both directions of rotation. Inasmuch as two pinions act on each intermediate gear, the width of the teeth could be somewhat reduced, but it is evident that, in order to ensure faultless operation, the various bore holes for the spindle intermediate shaft and the gear shafts must be absolutely parallel. The disc brakes are pressed together by means of springs which tend to eliminate vibration. All parts of the brake are lubricated by a system of modern design. The material used for the gears, bearings, etc., is mainly of Krupp special steel.

A gear-driven oil pump which operates in both directions is connected to one of the turbine shafts. It pumps lubricating oil from the reservoir and forces it directly into the pipe which distributes the oil to the various bearings. The usual modern devices used to lubricate high-speed pinions with spray and oil vapor, as well as an oil-cooling apparatus, are provided. The cooling effect of the air, when the locomotive is in motion, is utilized and provision is also made to cool the tubes of the oil-cooling apparatus with water, which is controlled by the engineman.

The two condensers are connected in parallel for both the flow of steam and of water. The cooling water flows in four streams, so that a high rate of flow is obtained. A separate group of cooling tubes for the trapped air is provided. Suitable care in the construction of the joints and the mode of adjustment of the tubes to prevent sagging has been taken and the tubes can be inspected or removed without having to remove the condenser from the locomotive.

The condensate flows from the condensers to an intermediate tank provided with a float gage. From here it is drawn off by the condensate pump which is directly connected to the feedwater pump. These pumps are surrounded by a water chamber connected to the feedwater reservoir in the tender. The condensate pump can only work up to atmospheric pressure; the feedwater pump forces water out of the reservoir into the boiler.

A by-pass in the feedwater pipe enables the engineman to allow the feedwater pump to run without load for a time, in order to enable the condensate pump to work independently. The speed of the pump can be controlled from the cab. In case the speed of the pump is not sufficient, the water in the intermediate tank is raised and the float gage indicates this in the cab. This warns the engineman to operate the pump at a greater speed. But, as the capacity of the condenser pump is about 20 % greater than the feedwater pump, this indication will not often occur. The air in the condensers is ejected by two steam ejectors, the exhaust steam from which is condensed in the feedwater heater.

The feedwater heater tanks are located in the rear of the condenser. The steam in one is under atmospheric pressure. This heater absorbs the exhaust steam from the feedwater pump, the air compressor, the two steam ejectors and the dynamo turbine, which heats the water coming from the condensers at from 110 to 120° up to 190 or 200° F. The water is then forced to the second feedwater heater to which steam is admitted at about 37 lb. gage pressure. This heater receives the exhaust from the turbine connected to the cooling water pump on the tender and part of the time it also receives the exhaust steam from the suction draft turbine, which reheats the water up to a temperature of about 260° F. Any superfluous steam passes through a regulating valve to a low pressure stage of the main turbine.

In order to save steam under all conditions, a small additional condenser is placed between the main condensers, in which the non-condensed steam from the

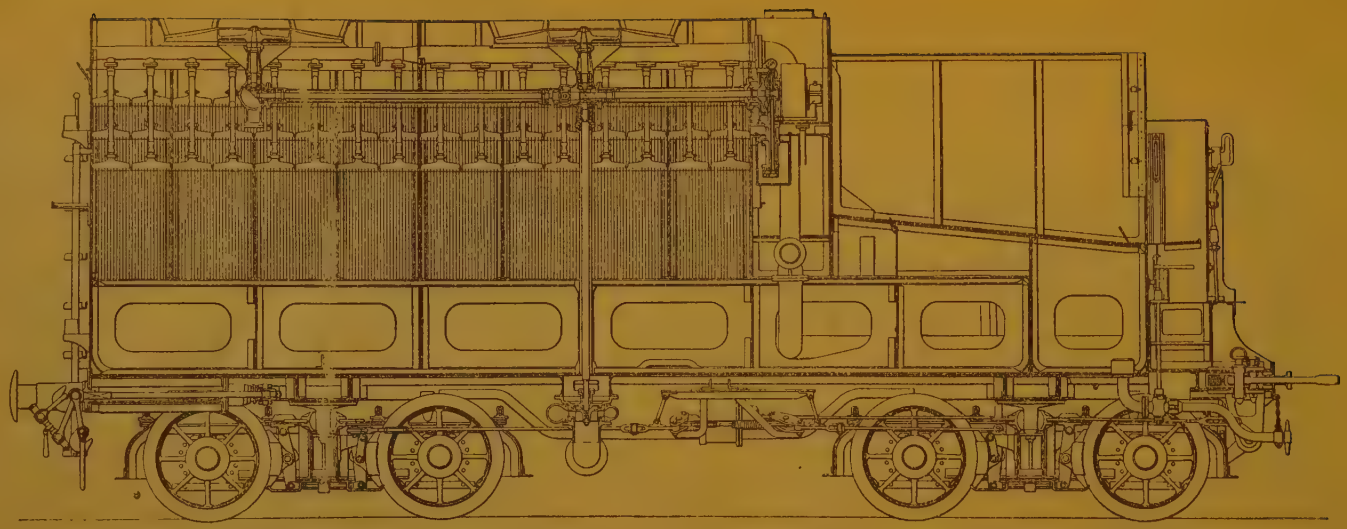


Fig. 7. — The tender, showing the location of the condenser and auxiliary equipment.

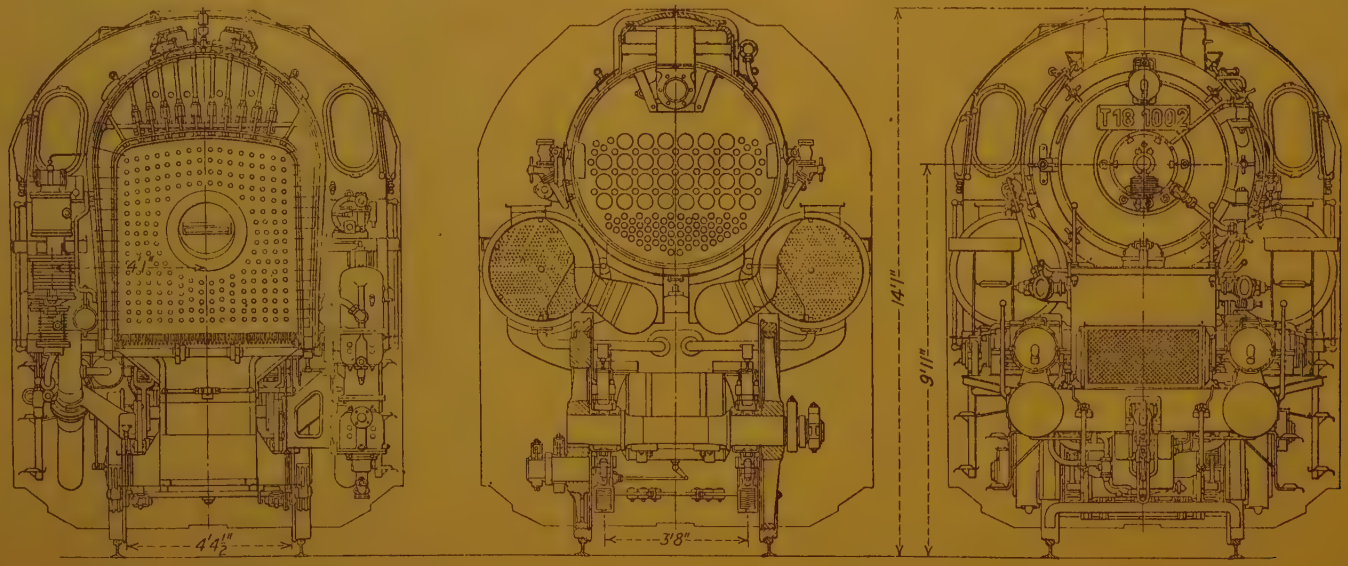


Fig. 8. — Cross sections through the firebox, smokebox and elevation drawing of the front end.

feedwater heater is condensed and the water flows back to the reservoir.

Two detachable rubber hose equipped with self-adjusting couplings, conduct the cooling water to and from the tanks of the tender. Live steam flows from the engine to the tender through a combination metal hose, located near the center line of the locomotive.

A novel construction was created in order to solve the important question of suitable draft in the smoke box. As may be seen from the drawings, a small high speed turbine is located in the door of the smoke box, which operates with superheated as well as with saturated steam. It is directly coupled to a draft fan of special design. This fan is extremely simple in design and form, made of non-rusting Bohlsteel, and ejects the gases from the smoke box.

The draft fan operates at a speed of from 6 to 7 000 revolutions per minute. This unit and its housing form the projecting point of the door which receives a strong cooling effect on the front bearing and the oil chambers directly adjacent, while the locomotive is running. The turbine casing has ribs cast on the outside to cause the air to circulate around the turbine and also to cool the bearings. The admission valve of the turbine is controlled directly by the engineman in the cab. The exhaust steam from the turbine flows into the second feedwater heater, and is controlled by a valve that admits the steam at a pressure of about 37 lb. per square inch gage. In case this heater is fully charged, the steam is turned into a low-pressure stage of the main locomotive turbine.

This draft system was thoroughly tested and it was found that the desired pressures could be obtained with high efficiencies. It has the advantage of high speed which enables it to be coupled up directly to a high speed turbine. The speed need only be adjusted by the throttling valve and it will remain constant, regardless of variations of the gases or other conditions. No extra regulating devices such as a safety cutout, etc., are necessary.

The tender has an overall length of 37 ft. 8 3/4 in. and is mounted on two four-wheel trucks. A water tank having a capacity of 1 138 gallons is located in the forward end and directly above it is the coal bunker having a capacity of 6 tons. A partition is inserted between the coal bunkers and the cooling compartment for the turbine driving the feedwater pump and the fans for the cooling compartment, to which access is provided from the top.

The turbine is geared to a main horizontal shaft from which the power is transmitted by means of bevel gears, to the vertical shafts of the fans and the cooling water pump. It operates at 6 000 revolutions per minute, whereas the cooling water pump and the two fans have a speed of 1 000 revolutions per minute. The fans require 13 H.P. and exhaust 882.5 cubic feet per second. The pump absorbs 23 H.P. and delivers 12 380 cubic feet per hour.

The rear and greater part of the tender is occupied by the cooling installation, but the space thus used is only about one tenth of that usually required for stationary installations. Extraordinary conditions being present made it imperative to find new methods and apply new principles. It was found by actual experiment to be very important to prevent drop formation, as a drop of water is carried away by the current of cooling air. The cooling air must follow a line of least resistance in order to save power for ventilation; vibration must be eliminated and all parts must be so located as to be easy of access. It is not possible to cool by means of a blast of air on account of the great amount of space required.

It must be considered that from about 16 million to almost 18 million British

thermal units per hour will have to be taken care of, a figure which is too great for air ventilation only. Air is admitted on both sides of the tender, passing through air deflectors and is ejected by means of two horizontal ventilators placed in the roof. The compartment for recooling is subdivided into various cooling elements. These elements, of which there are 48, consist of closely packed perforated sheet copper which are separated by pass pieces and held together by bolts. The air passes between the copper plates in an opposite direction from the downward flowing cooling water, which flows in sheets, thus avoiding drop formation.

The experiments proved that this construction insures the greatest economy of water and that the loss of water was not any greater than the evaporation determined by calculation. It is evident that with the cool water, the temperatures mentioned can create a satisfactory vacuum. At full load the locomotive has an average vacuum of from 80 to 90 % which increases at a lower load. It is possible under these circumstances to maintain a lower water temperature in the reservoir and begin the next period of heavy work with a better vacuum.

The exhaust of the auxiliary turbine on the tender, furnishes the necessary steam for heating the train at various pressures, according to temperature or other conditions. The turbine receives boiler pressure and the exhaust steam flows to the second feedwater heater drum in warm weather. Only that portion of the exhaust steam which is not used for train heating is supplied to the feedwater heater in cold weather. A small turbo-dynamo generates the necessary electric current for lighting.

Table of dimensions, weights and proportions of the turbine locomotive for the German State Railways.

Railroad	German State Railways.
Builder	I. A. Maffei, Munich, Germany.
Type of locomotive	4-6-2.
Service	Express.
Main turbine speed at 74.6 miles per hour	8 800 revolutions per minute.
Ratio of main reduction gear	1 to 24.
Weights in working order :	
On drivers	132 000 lb.
On front truck	66 000 lb.
On trailing truck	31 000 lb.
Total engine	229 000 lb.
Total tender	150 000 lb.
Total engine and tender	379 000 lb.
Wheel bases :	
Driving	13 ft. 1 1/8 in.
Total engine	36 ft. 6 9/16 in.
Total engine and tender	69 ft. 9 in.
Diameter driving wheels outside tires	68.8 inches.
Boiler :	
Type	Conical.
Steam pressure	324 lb.
Fuel	Soft coal.
Diameter, second ring, inside	64 7/8 inches.
Length inside tube sheets	17 ft. 2 in.
Grate area	37.7 square feet.

Heating surfaces:	
Firebox	140 square feet.
Tubes and flues	1 580 — —
Total evaporative	1 720 — —
Superheating	549 — —
Com. evaporative and superheating	2 269 — —
Tender:	
Capacity, cooling water tank	5 290 Am. gallons (4 405 British gallons).
Capacity, feedwater reservoir	1 138 Am. gallons (948 British gallons).
Fuel capacity	6 tons.
Condenser:	
Total surface	2 370 square feet.
Water cooling installation:	
Cooling surface	16 150 square feet.
Rate of cooling air circulation, 1 100 revolutions per minute of fans	1 765 cubic feet per second.
Rate of cooling water circulation	12 700 cubic feet per hour.
Floor space of cooler	122.8 square feet.
General data estimated:	
Horsepower	2 500.
Weight proportions:	
Total weight engine ÷ horsepower	91.5.
Total weight engine ÷ comb. heat. surface	101.
Boiler proportions:	
Firebox heat. surface ÷ grate area	3.72.
Firebox heat. surface, per cent of evap. heat. surface	8.14.
Superheat. surface, per cent of evap. heat. surface	31.9.

MISCELLANEOUS INFORMATION

[313 .385 (.5)]

1. — The World's railways during the years 1922, 1923 and 1924.

COUNTRIES.	Mileage open on 31 December			Area (square miles).	Population.	Mileage open at the end of 1924	
	1922	1923	1924			per 100 square miles.	per 10 000 inhabitants.
I. — EUROPE.							
Germany.	Miles.			Round figures.		Miles.	
Prussia (including the Saarre)	21 119.5	21 022.6	21 153.1	113 750	36 691 000	18.5	6.3
Bavaria (including the Palatinate)	5 402.3	5 485.0	5 513.5	29 500	7 140 000	18.7	7.7
Saxony	2 003.9	2 003.9	2 022.0	5 790	4 663 000	34.9	4.3
Wurtemberg	1 391.9	1 393.8	1 415.5	7 530	2 519 000	18.8	5.6
Baden	1 504.4	1 505.6	1 508.1	5 830	2 208 000	25.9	6.8
Other German States	4 401.9	4 367.7	4 417.4	19 850	6 632 000	22.2	6.6
Total for Germany.	35 823.9	35 778.6	36 029.6	182 250	59 853 000	19.8	6.0
Austria	3 938.9	4 153.3	4 373.3	32 350	6 647 000	13.5	6.6
Czechoslovakia	8 718.0	8 718.0	8 718.0	54 210	13 613 000	16.1	6.4
Hungary	5 921.1	5 921.1	5 921.1	35 790	8 119 000	16.4	7.3
Great Britain	24 396.7	24 396.7	24 396.7	94 990	44 517 000	25.7	5.5
France	33 281.8	33 281.8	33 281.8	212 750	39 210 000	15.6	8.5
Russia	30 800.7	35 027.3	35 708.4	1 444 460	67 336 000	2.4	5.3
Finland	2 665.7	2 728.5	2 821.1	150 000	3 365 000	1.9	8.4
Poland	9 871.9	11 974.7	11 974.7	149 930	27 193 000	8.0	0.4
Lithuania	1 938.7	1 938.7	1 938.7	21 350	2 035 000	9.0	9.5
Lettonia	1 770.3	1 754.8	1 754.8	25 410	1 596 000	6.9	11.0
Esthonia	890.4	890.4	890.4	18 340	1 107 000	4.8	8.0
Italy	12 500.9	12 840.2	12 840.2	119 660	38 756 000	10.8	3.3
Belgium	6 893.0	6 893.0	6 893.0	11 740	7 666 000	58.7	9.0
Luxemburg	334.3	334.3	334.3	1 000	261 000	33.3	12.8
Holland	2 140.7	2 140.7	2 264.9	13 210	6 865 000	17.2	3.3
Switzerland	3 323.1	3 571.7	3 571.7	15 950	3 902 000	22.5	9.1
Spain	9 643.9	9 676.1	9 676.1	195 140	21 658 000	5.0	4.5
Portugal	2 129.5	2 129.5	2 129.5	35 480	6 033 000	6.0	3.5
Denmark	3 086.4	3 086.4	3 096.3	16 600	3 381 000	18.7	9.1
Norway	2 140.7	2 147.5	2 147.5	125 030	2 650 000	1.8	8.1
Sweden	9 436.3	9 555.6	9 765.0	173 170	6 006 000	5.6	15.9
Yougoslavia	5 699.3	5 699.3	5 699.3	96 140	12 017 000	6.0	4.7
Roumania	7 325.4	7 322.4	7 322.4	113 900	16 500 000	6.4	4.4
Greece	1 983.5	1 983.5	1 983.5	50 200	5 065 000	4.0	3.9
Albany	40.4	186.4	186.4	14 520	877 000	1.3	2.1
Bulgaria	1 624.3	1 624.3	1 624.3	39 810	5 008 000	4.0	3.2
Turkey in Europe	257.3	257.3	257.3	1 160	1 000 000	22.2	2.57
Malta, Jersey, Isle of Man	68.4	68.4	68.4	430	375 000	16.1	1.9
Total for Europe.	228 645.5	236 080.5	237 668.7	3 444 970	412 611 000	6.9	5.8

COUNTRIES.	Mileage open on 31 December			Area (square miles).	Population.	Mileage open at the end of 1924	
	1922	1923	1924			per 100 square miles.	per 10 000 inhabitants.
II. — AMERICA.	Miles.			Round figures.		Miles.	
Canada	39 541.0	39 861.7	40 093.4	3 729 880	8 788 000	1.1	45.4
United States of America (including Alaska)	252 241.4	251 162.6	250 970.7	3 625 240	106 139 000	6.9	23.6
Newfoundland	950.7	952.6	952.6	162 940	263 000	0.6	36.2
Mexico	16 443.0	16 443.0	16 443.0	760 340	14 235 000	2.1	11.6
CENTRAL AMERICA :							
Guatemala	613.3	681.0	684.8	42 360	2 005 000	1.6	3.4
Honduras	559.3	811.5	811.5	38 680	673 000	2.1	12.1
Salvador	256.0	256.0	256.0	13 170	1 582 000	1.9	1.6
Nicaragua	200.0	200.0	200.1	49 230	638 000	0.3	3.1
Costa-Rica	545.6	667.4	667.4	23 010	498 000	2.9	13.4
Panama	297.6	469.1	469.1	32 400	434 000	1.5	10.8
GREATER ANTILLES :							
Cuba	3 005.0	3 722.7	3 722.7	44 210	3 123 000	8.4	11.9
Dominican Republic	408.3	408.3	408.3	19 340	895 000	2.1	4.5
Haïti	167.2	173.4	173.4	11 080	2 045 000	1.6	0.9
Jamaica	198.8	200.1	200.1	4 210	858 000	2.1	2.3
Porto-Rico	339.9	339.9	339.9	3 440	1 365 000	9.8	2.5
LESSER ANTILLES :							
Martinique	139.1	185.2	185.8	390	244 000	48.1	7.6
Barbadoes	497.8	497.8	497.8	160	156 000	3.2	3.2
Trinity	108.1	173.4	173.4	1 970	366 000	8.9	4.7
Antigua	...	...	19.9	110	19 000	17.2	10.4
Virgin Isles	...	...	29.8	80	5 000	38.6	60.0
Bahama Isles	...	...	9.9	4 400	53 000	0.2	1.9
St. Christofer (St. Kitts)	...	...	16.1	80	17 000	20.9	8.1
United States of Columbia	925.9	1 020.3	1 020.3	495 390	5 855 000	0.16	1.7
Venezuela	659.9	659.9	659.9	393 990	2 491 000	0.16	2.7
British Guiana	103.8	103.8	103.8	89 500	298 000	0.16	3.5
Dutch Guiana	37.3	37.3	37.3	54 330	111 000	0.06	3.4
Ecuador	651.8	651.8	651.8	118 540	2 000 000	0.5	3.2
Peru	1 988.4	2 075.5	2 075.5	532 220	5 550 000	0.32	3.7
Bolivia	1 502.5	1 502.5	1 502.5	567 670	2 890 000	0.32	5.2
Brazil	18 704.2	18 704.2	18 704.2	3 281 020	30 636 000	0.5	6.1
Paraguay	308.8	308.8	308.8	171 820	1 000 000	0.16	3.1
Uruguay	1 652.9	1 652.9	1 659.1	72 160	1 603 000	2.3	10.3
Chili	5 301.0	5 049.9	5 381.8	289 820	3 755 000	1.9	14.4
Argentine Republic	23 156.4	23 156.3	23 482.0	1 153 170	9 548 000	1.9	24.2
Total for America.	371 505.0	372 128.9	372 912.7	15 786 350	210 138 000	2.4	17.8
III. — ASIA.							
Central Russia and Siberia	6 556.2	7 083.8	10 185.7	6 363 070	97 857 000	1.7	1.1
China	6 837.6	7 173.2	7 173.2	4 301 130	440 139 000	0.16	0.2
Japan, including Corea, Formosa and Kwantung	12 284.1	13 109.9	13 109.9	265 150	77 728 000	5.0	1.7

COUNTRIES.	Mileage open on 31 December			Area (square miles).	Population.	Mileage open at the end of 1924	
	1922	1923	1924			per 100 square miles.	per 10 000 inhabitants
	Miles.			Round figures.		Miles.	
British India	(1) 40 491.1	(1) 38 068.5	(1) 38 068.5	1 828 570	318 942 000	2.0	1.2
Ceylon	731.9	732.6	732.6	25 330	4 505 000	2.9	1.6
Persia	350.4	350.5	350.5	628 210	10 000 000	0.05	0.4
Asia Minor, Syria, Arabia with Cyprus	3 828.9	3 828.9	3 828.9	1 418 280	21 311 000	0.32	1.8
Palestine	...	695.9	695.9	9 000	757 000	7.7	9.2
Portuguese Indies	54.0	54.0	54.0	1 470	579 000	3.7	0.9
Malay States	1 163.2	1 163.2	1 163.2	52 090	2 448 000	1.4	7.6
Dutch Indies (Java, Sumatra)	1 882.7	1 894.6	1 894.6	733 700	49 351 000	0.32	0.4
North Borneo, Sarawak	...	...	139.8	78 960	889 000	0.17	1.6
Siam	1 422.9	1 538.6	1 538.6	195 060	9 207 000	0.5	2.7
Cochinchina, Camboja, Annam, Tonkin	1 490.0	1 490.1	1 490.1	274 450	19 122 000	0.5	0.7
Pondicherry	59 0	59.0	59.0	120	172 000	51.0	3.4
Philippine Isles	809.6	809.7	809.7	115 020	10 953 000	0.7	0.75
Total for Asia	77 961.6	78 052.5	81 294.2	16 289 610	1 063 960 000	0.5	0 75
IV. — AFRICA.							
Egypt (including Sudan)	4 894.0	4 894.0	4 894.0	1 364 920	19 629 000	0.32	2.5
Algiers and Tunis	4 219.8	4 219.8	4 219.8	270 510	7 896 000	1.6	5.3
Marocco	861.9	884.9	884.9	162 170	5 480 000	0.5	1.6
Belgian Congo	1 263.3	1 273.2	1 273.2	979 540	7 153 000	0.16	1.8
South African Union	11 475.7	11 570.1	11 744.7	473 110	6 929 000	2.5	1.7
Colonies.							
ENGLAND :							
British East Africa (including Zanzibar)	851.3	692.9	692.9	431 990	5 945 000	1.6	1.2
Ex-German East Africa (Tanganyka)	891.7	891.7	1 019.1	365 110	4 107 000	0.3	2.5
Rhodesia	2 457.6	2 457.6	2 471.2	440 020	1 883 000	0.5	13.1
Betchuanaland	425.1	425.1	425.1	275 070	153 000	0.16	27.8
British Central Africa (Nyassaland)	173.9	173.9	173.9	39 960	1 202 000	0.3	2.3
Sierra-Leone	334.9	338.0	354.8	24 900	1 541 000	1.4	2.3
Gold Coast	193.9	193.9	302.0	80 270	2 078 000	0.37	1.4
Nigeria	1 125.9	1 125.9	1 125.9	336 190	18 750 000	0.32	0.6
Mauritius	133.6	144.2	144.2	730	377 000	19.6	3.9
South West Africa	1 307.4	1 413.6	1 680.2	322 450	228 000	0.5	73.7

(1) According to a communication received from the Government of India, Railway Department, the correct open mileage of all railways in British India is as stated hereafter :

Year ending 31 March	1923	37 617.9 miles.
— —	1924	38 038.5 —
— —	1925	38 269.8 —

(*Editorial note.*)

COUNTRIES.	Mileage open on 31 December			Area (square miles).	Population.	Mileage open at the end of 1924	
	1922	1923	1924			per 100 square miles.	per 10 000 inhabitants.
FRANCE :	Miles.			Round figures.		Miles.	
French West Africa	1 713.8	1 713.8	1 713.8	356 580	2 475 000	0.5	6.9
Togo	203.2	204.5	206.3	20 080	670 000	1.0	3.1
Cameroun	192.6	246.7	282.7	166 530	3 000 000	0.17	0.9
French Somali Coast (Abyssinia)	495.2	495.2	495.2	46 330	65 000	1.1	76.2
French Equatorial Africa	335.6	335.6	(1) 335.6	871 040	2 851 000	0.03	1.2
Madagascar	402.1	435.6	600.3	223 950	3 278 000	0.32	1.8
Reunion	78.9	78.9	78.9	930	173 000	8.5	4.5
PORTUGAL :							
Angola	818.3	818.3	818.3	484 880	4 182 000	0.16	1.9
Mozambique	454.8	454.8	520.7	293 450	3 120 000	0.16	1.7
Total for Africa.	35 304.5	35 482.2	36 457.7	8 030 710	103 165 000	0.45	3.5
V. — AUSTRALIA.							
New Zealand	3 011.2	3 029.3	3 084.5	104 750	1 219 000	2.9	25.3
Victoria	4 349.1	4 377.0	4 483.3	87 880	1 531 000	5.0	29.3
New South Wales	5 443.9	5 477.5	5 654.6	309 470	2 100 000	1.8	26.9
South Australia	3 467.3	3 488.4	3 488.4	380 090	495 000	1.0	70.5
Queensland	7 022.9	7 067.0	7 067.0	670 530	756 000	1.1	93.5
Tasmania	867.5	873.1	873.1	26 220	214 000	3.4	40.8
West Australia	4 839.3	4 869.8	4 869.8	975 950	333 000	0.3	235.3
North Territory	197.6	198.8	198.8	523 650	3 867 000	0.032	0.5
Territory of the Federal Capital	4.9	4.9	4.9	930	2 572 000	0.5	0.018
Hawaï (with the Isles Maui and Oahu)	242.9	242.9	242.9	6 450	256 000	3.7	9.5
New Caledonia	...	...	18.7	7 220	47 000	0.26	4.0
Total for Australia.	29 446.6	29 628.7	29 986.0	3 093 140	13 390 000	1.0	22.4
RECAPITULATION.							
Europe	228 645.5	236 080.5	237 668.7	3 444 970	412 611 000	6.9	5.8
America	371 505.0	372 128.9	372 912.7	15 786 350	210 138 000	2.4	17.8
Asia	77 961.6	78 052.5	81 294.2	16 289 610	1 063 960 000	0.5	0.75
Africa	35 304.5	35 482.2	36 457.7	8 030 710	103 165 000	0.45	3.5
Australia	29 446.6	29 628.7	29 986.0	3 093 140	13 390 000	1.0	22.4
Total for the World.	742 863.2	751 372.8	758 319.3	46 644 780	1 803 264 000	1.6	4.2

(1) Corrected figure.

[656 .254 (.73)]

2. — Electric highway crossing protection with automatic operating features.

Fig. 1, p. 548.

(*Railway Signaling.*)

An automatic electric highway crossing signal has been developed and manufactured by O. L. Vincent, Chicago. As installed for trial on a double-track line of a large steam railroad in the vicinity of Chicago, where there are approximately 50 trains a day, this device includes the following features.

One unit is installed on each side of the

Fig. 1.

Above. — New electrically operated device with arms lowered across highway.
Below. — View illustrating arm being forced aside to prevent damage to arm or automobile.

railroad on the right side of the highway when approaching the crossing. The signal unit consists of the arm, the operating mechanism, and the housing for the operating mechanism which also supports the arm, and an independent disk and light. Three red lights are mounted equi-distant on the arm which flash in unison with the light in the disk on the signal head such that these four lights start to flash down the highway providing a prewarning five

seconds or more before the arm starts to lower and continue to burn while the arm is down and until it is again returned to the vertical position.

The lights on the arm are so hooded as to shine both ways on the highway but not down the track. Therefore, when the gates are down as shown in the illustration, an indication of seven red lights all the way across the highway is presented to a driver of an approaching automobile.

The operating mechanism includes a 1/6 H.P. motor, which operates the arm through gears and friction clutches; also a rotary circuit controller for controlling the flashing lights and controlling the starting and stopping of the motor and also locking in both the up and the down position. The controller allows the motor to get up to speed before taking on the load.

An outstanding feature of this new device is that it can be lowered on top of an automobile without injury to the vehicle, it can be pushed aside when in the lowered position without injury to an automobile and when again operated will resume normal position. This feature is accomplished by the fact that the arm is hinged on a movable head that revolves in a horizontal plane on ball-bearings; two helical springs keep the normal position of this head.

The mechanism that lowers or raises the arm has a clutch feature that allows the arm to be stopped when striking the top of a car, although the motor and mechanism continue its cycle of operation and on the return movement brings the arm back to its correct position. Small cables may be provided on the sides and bottom to assist in throwing the gate aside without injury to a vehicle. The movable head feature of the device permits the arm to swing slightly in a heavy wind floating against the helical springs, which feature prevents wrecking the signals on account of wind.

The manufacturer recommends a gate arm of such length that it will extend slightly more than one-half way across the highway on the side on which traffic is approaching the railroad, both arms presenting the appearance of gates entirely across the highway. In case a driver of an automobile should be caught on the tracks when the arms are down he can either push the gate to one side with the car or he is free to go around the end. In case the arms should happen to be temporarily down due to track circuit failure, the drivers of automobiles can get across the track without serious delay by making an « S » curve around the ends of the two arms.

Where the railroad desires that four gates be provided, the mechanism can be so controlled by a master switch such that the two gates on the traffic side of the highway are lowered as many seconds prior to the other two as may be desired, thus allowing time for any cars caught on the track to get out before the final gates are lowered.

Due to the unique features, this signal is adaptable for remote country crossings as well as the busier crossings, being controlled either automatically by track circuits or manually. It is recommended for congested territories where one man can with safety control a large number of such signals and thus have jurisdiction over numerous crossings.

[625 .111 (.73)]

3. — Relocation reduces grades from 6 to 3 per cent.

Fig. 2, p. 550.

(*Engineering News-Record.*)

Difficult location and heavy rock excavation for grading are involved in the reconstruction of the Kenilworth branch of the Denver & Rio Grande Western Railroad, in Utah, by which the original maximum grade of 6.1 % has been reduced to 3 %. In the rough and broken mountainous country such a favorable relocation seemed almost impossible, but the great increase in traffic made it imperative that the problem should be solved, since the

output of mines served had reached the limit of traffic capacity on the original line.

Several years ago when the Independent Coal & Coke Co. opened the Kenilworth mine, about four miles east of Helper, Utah, a standard-gage railroad to the mine was constructed by the coal company, having a junction with the Denver & Rio Grande Western Railroad main track at a point just beyond the east end of the yard at Helper. This line, known as the Kenilworth & Helper Railroad is 3.74 miles in length, with maximum grades of 6.10 % and a maximum rate of curvature of 10°. The elevation of the junction is 5 780 feet and the elevation at the Kenilworth mine is 6 604 feet, thus producing an average grade of about 4.2 % without compensation for curvature. For seven years the line was operated by the coal company, using geared locomotives, but in 1914 the road, with its equipment,

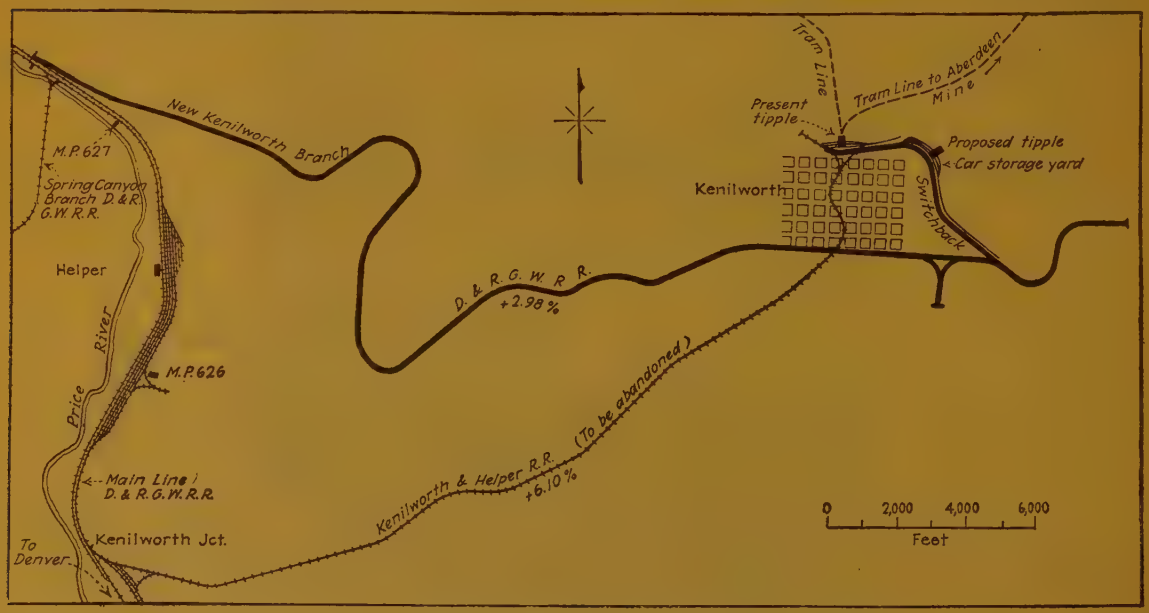


Fig. 2. — Railroad relocation in Utah : Denver & Rio Grande Western.

was leased to the Denver & Rio Grande Western Railroad, which has operated it since that time.

A tonnage train to the mine for two geared locomotives coupled together consists of thirteen empty cars, while the same number of loaded cars is the maximum permissible train load descending from the mine. The production of the Kenilworth mine has increased steadily and recent plans of the coal company contemplate still further increase in production by a new opening known as the Aberdeen mine, adjacent to the Kenilworth and at about the same elevation. The combined capacity production with the large modern colliery facilities proposed for the Aberdeen mine will amount to 5 000 tons per day, or 100 carloads of the average 50-ton capacity cars. A tonnage traffic of this magnitude is entirely beyond the operating capacity of the present Kenilworth & Helper Railroad, while even half that tonnage imposes difficulties and operating expenses incommensurate with the revenues.

Under these circumstances it was decided to build a new line on such grades as to give an operating capacity sufficient for the entire ultimate production of the Kenilworth and

Aberdeen mines and for any reasonable increase resulting from the opening of additional mines in the immediate vicinity. This line, shown in the accompanying plan and now under construction, is 6.28 miles in length, including about a mile of switchback line to serve both mines in setting in empties and taking out loads. The switchback line is constructed with a maximum grade of 1.65 %, heavier grades being impracticable in the gravity operation of tipple and storage tracks, space for which is at a premium. From the junction to the switchback there is a continual rise, with grades ranging mainly from 2 to 3 %.

The new branch divorges from the main line of the Denver & Rio Grande Western Railroad near the west end of the yard at Helper, and thence extends in an easterly direction over rough and broken country by means of a 3 % supported grade line compensated for curvature, of which the maximum rate is 10°. The formidable territory traversed lies immediately under high sandstone cliffs and is strewn with immense boulders and fragments of the stratified material of which the cliffs are constituted. Such timber as is encountered along the line consists of scraggly red cedar in moderately thick stands.

The alignment is severe, with a large aggregate amount of total angle, owing to the ruggedness of the country and the necessity of employing a supported grade line. The profile is deeply serrated, with some large cuts and fills. Steep slopes along which the line is built add large quantities to the excavations and embankments, not indicated by the center-line profile. The material consists of moderately heavy classification, the solid rock being largely boulders and hard blue shale.

Owing to the difficulty of close classification of the materials, the contract was let for a unit price of excavation without classification, a price for borrow, and a price for overhaul beyond a limit of 500-foot free haul. Construction of reinforced-concrete box culverts, mass concrete headwalls for pipe culverts, and placing of the culvert pipe were included in the contract for grading. This contract, awarded 6 April 1926, involved the handling of about 500 000 cubic yards of material, and since it had to be completed to permit finishing the track work before the season of inclement weather, a large amount of construction equipment was employed. Although the line to be constructed lay within four miles from the operated line, yet because of the extreme roughness of the country traversed, great difficulty was experienced in getting steam shovels and equipment to different parts of the work. Considerable time was consumed also in laying pipes on the heavy sections of the line to supply water and compressed air for prosecution of the work. There are eight units of shovel equipment with narrow-gage engines, cars, and dump wagons on the job, and several of these units have been worked on double shifts.

Owing to the difference in elevation of the new and old lines at their intersection, which difference was too great to permit a grade crossing or temporary connection and too little to permit an undercrossing of the old line, and owing also to the necessity of serving the Kenilworth mine without interruption, that portion of the new track above its crossing with the old line will have to be laid from the Kenilworth end, while that portion below the crossing will be laid from the main line end, the two being connected and put into service immediately on cutting the old line at the point of crossing. The difference in elevation of the new and old tracks at Kenilworth also requires temporary switches to avoid delay in operation of the mine while change in train service is being made from the old to the new line. A wye at Kenilworth and a convenient layout of the coal company's tipple and storage tracks with track scales and crossovers complete the transportation facilities, so that full tonnage trains both of empties up and loads down can be moved with ordinary locomotives at minimum expense.

Surveys. — In such difficult mountain country it is not practicable to make a definite and final location with one survey. Ordinarily it requires a preliminary line which, according to the judgment of the locating engineer, is more or less closely followed in the final loca-

tion. This preliminary is an angle line only, and if a supported grade is necessary, the line is kept close to the grade elevation. Topography is taken along the preliminary line and a projected location made from a topographical contour map. In heavy mountain construction, also, it is usually impossible to fit the location to the country so as to produce the most economical results. By projecting a location on the topographical map, the many attempts in fitting the line in the field are avoided and much expense is therefore eliminated. The projected location is followed in the final field location, but modified and improved as circumstances warrant. In this particular case there was no question of the economic value of reconstruction, since the traffic capacity of the old line was actually insufficient. Local circumstances and topographic conditions determined the 3 % grade for the new line.

This relocation and reconstruction work was done under the direction of Arthur Ridgway, chief engineer of the Denver & Rio Grande Western Railroad, with L. O. Doane as engineer in charge. The contract for roadbed complete, ready for tracklaying, was awarded to the Utah Construction Co., Ogden, Utah, the tracklaying being done by railroad forces.

[621 .152.5 (.73)]

4. — New Delaware & Hudson high pressure locomotive.

Figs. 3 and 4, pp. 554 to 555.

(From the *Railway Age*.)

A cross-compound *Consolidation* type locomotive, carrying a working boiler pressure of 400 lb., was delivered to the Delaware & Hudson by the American Locomotive Company on 2 February 1927. It has since been operating in *freight service* between Oneonta, N. Y., and Mechanicsville. This locomotive, which has been named the *John B. Jervis* in honor of the memory of the first chief engineer of the Delaware & Hudson Canal Company, is of essentially the same design as the *Horatio Allen*, its predecessor by a little more than two years.

John E. Muhlfeld, consulting engineer for the railroad is responsible for the design of both locomotives. They both have water tube fireboxes of unique construction; both carry much higher boiler pressures than are common locomotive practice, and both have cross-compound cylinders. The boiler pressure of the new locomotive, however, is 50 lb. higher than the 350 lb. of the *Horatio Allen*, and several changes have been made in the proportions of the firebox. By the elimination of certain auxiliary devices and by refinements of the design in various details, the weight has also been considerably reduced. The appearance of the locomotive has been changed from that of the *Horatio Allen* by the remodeling of the jacketing.

A comparison of the principal dimensions and proportions of the two locomotives is given in the table. Aside from the points already alluded to, it will be seen that the cylinder diameters are smaller, so that, with the higher boiler pressure, they develop substantially the same tractive force.

Principal dimensions of the *John B. Jervis* and the *Horatio Allen*.

	John B. Jervis.	*Horatio Allen.*
Weight on drivers	295 000 lb.	298 500 lb.
Total weight	336 500 lb.	348 000 lb.
Total evaporative heating surface	3 121 square feet.	3 200 square feet.
Superheating surface	700 — —	579 — —
Grate area	82 — —	71.4 — —
Cylinders	22 1/4 in. and 38 1/2 in. by 30 in.	23 1/2 in. and 41 in. by 30 in.

Diameter of driving wheels	57 inches.	57 inches.
Boiler pressure	400 lb.	350 lb.
Cylinder tractive force :		
Compound	70 800 lb.	70 300 lb.
Simple	85 000 lb.	84 300 lb.
Tractive force of auxiliary locomotive	18 000 lb.	18 000 lb.

The boiler.

The boiler has a water tube firebox and a fire tube barrel, the latter of relatively small diameter and completely filled with water. The steam space is in the steam drums of the firebox which are carried forward well beyond the firebox and connected to the barrel near their front ends.

It will be remembered that the heating surface in this firebox is not entirely of water tubes (1). The back head and rear fire tube sheet connections are water leg headers, each built of parallel stayed sheets, through which pass the two 20-inch water drums at the top. Ports through the drum shells in the header spaces, provide for circulation between the drums and headers. The front extensions of the steam drums pass through a saddle connection of parallel stayed sheets which is riveted to the boiler shell. Circulation between the barrel and steam drums, through the saddle, takes place through ports in the shells. The barrel shell is riveted into a flanged opening in the front wall of the front water leg and the rear fire tube sheet is riveted into a similar opening in the back wall of this water leg.

The outstanding difference in the boiler of the *John B. Jervis*, as compared with that of the *Horatio Allen*, is an increase of 15 inches in the length of the firebox, and an increase of 3 inches in the width of the firebox, the water drums having been spread that much farther apart. This effects the increase in grate area noted in the table.

In the *Horatio Allen* the heating surfaces of the sides of the firebox were made up of 306 tubes, about two thirds of which were 2 inches in diameter and the remainder 2 1/2 inches in diameter. The ends of these tubes were arranged in six staggered rows where they entered the water and steam drums, the two outside rows on each side, however, really forming one solid row of tubes along the sides of the firebox, against which the lagging was applied. In the new locomotive there are only 286 tubes, all 2 1/2 inches in diameter, arranged in five rows throughout their length. The sides of the firebox are closed with panels of Ascoloy steel sheets, the ability of which to withstand the high temperatures incidental to contact with the fire has been demonstrated by special tests. The lagging is applied outside of these sheets. Just above the water drums along each side of the firebox, a number of handhole openings are secured to the firebox wall sheets. These permit cleaning off from the tops of the drums and from the fire tubes of any accumulation of ash which may have been carried over from the grates, without knocking the fire.

While these changes have effected some slight variations in the heating surface distribution in the two locomotives, the only change of moment is the increase in the superheating surface from 579 to 700 square feet. Experience with the *Horatio Allen* and other tests have indicated that no difficulty need be anticipated from maximum steam temperatures considerably in excess of 600° F., for which the superheater in the *Horatio Allen* was originally proportioned. The superheater in the *John B. Jervis* is proportioned to produce a maximum steam temperature of about 700°.

The interior firebox arrangement is essentially the same in both locomotives. The brick arch extends the entire length of the firebox and causes the gases to flow outward and up through the five longitudinal staggered rows

(1) For a description of the *Horatio Allen*, see the *Bulletin of the Railway Congress* for February 1926, page 130.

Fig. 3. — The *John B. Jervis* develops a maximum tractive force of 103 000 lb.

of water tubes on each side, thence into the combustion space above the arch and to the fire tubes. As in the boiler of the *Horatio Allen*, eight longitudinal water tubes are located between the firebox headers at the top of the combustion chamber. The auxiliary superheater ,which was located in the firebox of the *Horatio Allen*, has been omitted in the new locomotive.

In the *Horatio Allen* four pipe connections were carried up from the top of the boiler barrel and connected alternately to the two steam drums. Considering that with the steam collector arrangement used in the steam drums of both locomotives, steam is collected over a wide area of water surface, and that approximately 75 % of the steam is generated in the firebox, the saddle and header connections between the boiler shell and the steam drums are believed to provide all the communication necessary. These pipe connections have, therefore, been omitted in the boiler of the *John B. Jervis*.

Steam distribution.

In the main superheater the spiral type of unit construction has been retained in the new locomotive. Each unit of this superheater consists of a single loop, the saturated end of which is formed in a spiral around the straight return pass. Attention has already been called to the increase in the number of units from 42 to 52.

The arrangement of the header is essentially the same as in the *Horatio Allen*, but the use of a so-called front end throttle valve permits the superheater steam for the auxiliaries to be taken directly from the main superheater header, on which a flanged opening is cast for that purpose.

Several changes have been made in the steam pipe arrangement. In the *Horatio Allen* a centrifugal type desaturator was placed in the steam pipe on the boiler side of the throttle, which in turn was located on the boiler side of the superheater. The desaturator has been omitted in the *John B. Jervis*. The double throttle valve of the former locomotive, the purpose of which was to limit the pressure to 300 lb. when operating simple, has been replac-

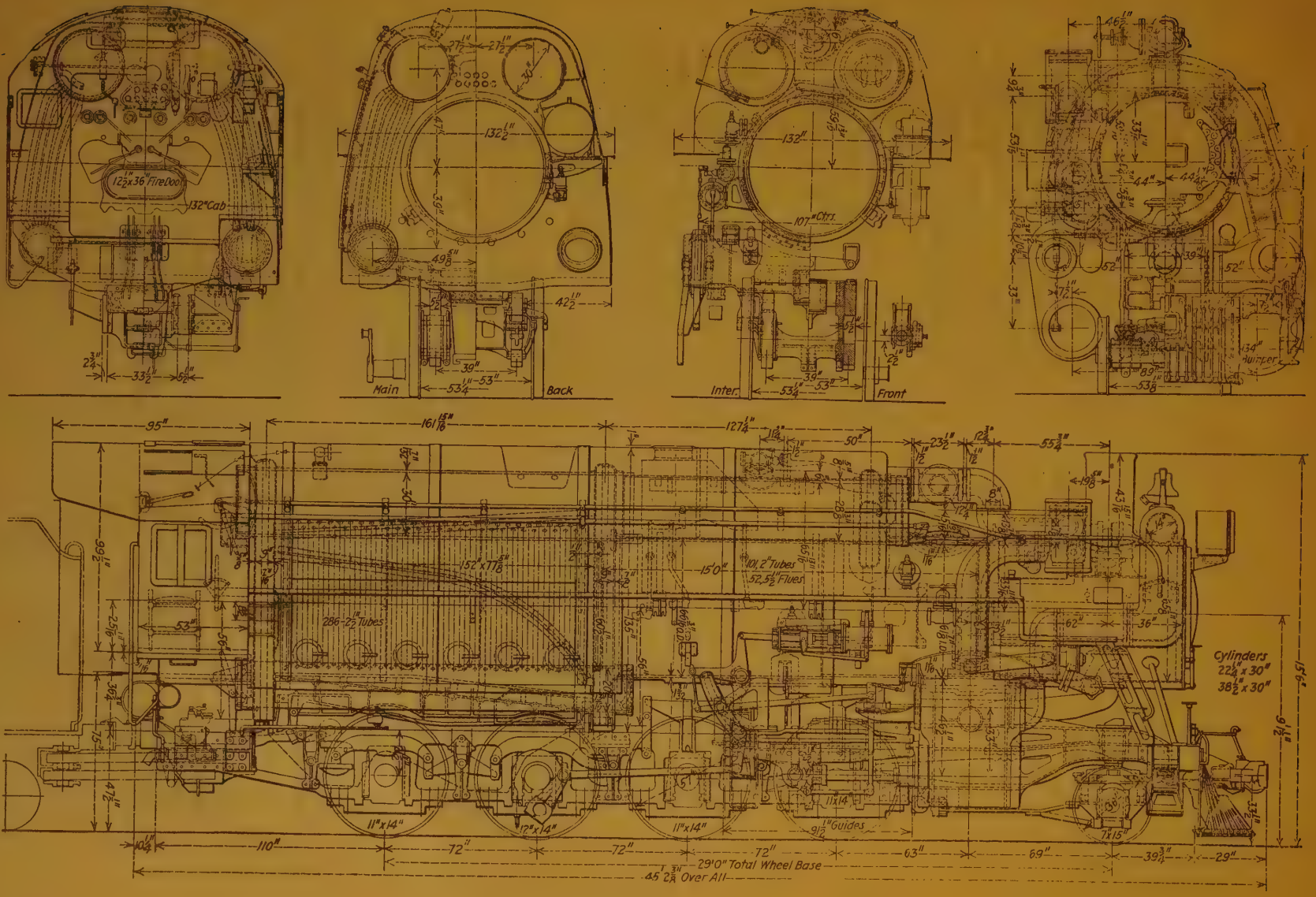


Fig. 4. — Cross sections and elevation of the *John B. Jervis*.

ed with a new type single seat Bradford throttle which is located on the cylinder side of the superheater.

Aside from this, the principal change in the steam pipes is an increase in the diameter of the receiver pipe from 10 inches were it leaves the Mellin intercepting valve, to 14 inches where it passes over the smoke arch. The diameter of the receiver in the *Horatio Allen* was 10 inches throughout. Superheated steam for the auxiliary locomotive on the tender is taken from the high pressure cylinder branch pipe. The steam distribution is controlled by a Walschaerts valve gear operating a 12-inch piston valve in the high pressure valve chamber and a 14-inch double operated piston valve in the low pressure valve chamber.

The cylinders and frames are essentially of the same construction in the *John B. Jervis* as in the former locomotive. In both locomotives the main frames terminate just back of the cylinders, where they are bolted to a combined steel saddle casting and front deck plate. To this casting is bolted the high pressure cylinder on the right side and the low pressure cylinder on the left side. The smokebox saddle fit is a separate casting which is bolted to the top of the main saddle casting, thus permitting the removal of the boiler without disturbing the smokebox saddle fit or the main frame splice. In the *John B. Jervis*, however, the combined steel saddle and deck casting has been redesigned and the weight reduced. A further material reduction in weight was also effected by the use of manganese cast steel for both the high and low pressure cylinders, which in the *Horatio Allen* were of cast iron. This reduction in cylinder weight is one of the principal factors in reducing the weight of the engine truck from 49 500 lb. in the case of the *Horatio Allen* to 41 500 lb. in the case of the new locomotive.

Other changes.

Particular attention was given to improving firebox draft and combustion with a view to reducing cylinder back pressure and fuel consumption. To assist toward this end, the new locomotive has been equipped with a trial application of the German State Railways' type of draft appliance. In this front end arrangement all baffle plates are removed from the smokebox, and the drafting appliances consist only of a low exhaust nozzle, the base of the tip of which is only about 15 inches above the bottom of the smoke arch, a cylindrical netting enclosure which extends from the nozzle to the base of the stack, and the stack itself. Beyond these appliances there is nothing in the smokebox except the front ends of the superheater units. The header itself, as in the case of the *Horatio Allen*, is located outside of the smokebox shell.

No outstanding changes have been made in the running gear, although there has been a refinement of some of the details. One of the changes consists in the use of Edmonds oil lubricated driving boxes on the main pair of journals.

Special attention was given to the cab and boiler head arrangements, and a very comfortable and convenient cab is the result. Comfortable seats have been provided on both sides of the cab, that on the fireman's side providing room for the head brakeman as well as the fireman. Particular attention was given to the ventilation of the cab and clear vision front windows are provided on both the right and left sides.

In order to eliminate stopping heavy freight trains for fuel and water, a larger-capacity tender has been used with the *John B. Jervis*. This has a capacity of 16 000 gallons of water and 20 tons of coal. It is carried on a Commonwealth six-wheel front truck and a six-wheel Bethlehem auxiliary locomotive under the rear end.

The *John B. Jervis* is reported to have gone into service in a very satisfactory manner both with respect to the running of the machinery, the steaming capacity and the superheat. The steaming has been exceptionally free and it is reported that it has been necessary to keep the fire door open a considerable part of the time to prevent loss of steam through the pops. The new throttle has proved to operate very satisfactorily and to be entirely free from any leakage. In order that accurate data may be obtained with respect to the performance of

the locomotive, dynamometer car tests will be made.

The principal dimensions, weights and proportions are shown in the following table.

Table of dimensions, weights and proportions of the *John B. Jervis*.

Railroad	Delaware & Hudson.
Type of locomotive	2-8-0.
Service	Freight.
Cylinders, diameter and stroke	22 1/4 and 38 1/2 inches by 30 inches.
Valve gear, type	Walschaerts.
Valves, piston type, size	12 and 14 inches.
Weights in working order :	
On drivers	295 000 lb.
On front truck	41 500 lb.
Total engine	336 500 lb.
Tender	303 000 lb.
Wheel bases :	
Driving	18 feet.
Rigid	18 —
Total engine	29 —
Total engine and tender	74 ft. 11 1/2 in.
Wheels, diameter outside tires :	
Driving	57 inches.
Front truck	36 —
Journals, diameter and length :	
Driving, main	12 by 14 inches.
Driving, others	11 by 14 —
Front truck	7 by 15 —
Boiler :	
Type	Combined water and fire tube.
Steam pressure	400 lb.
Fuel, kind	Mixed anthracite and bituminous.
Diameter, first ring, inside	61 7/8 inches.
Firebox, length and width	152 by 77 5/8 inches.
Arch tubes, number and diameter	6 — 3 1/2 inches.
Fire tubes, number and diameter	101 — 2 —
Fire flues, number and diameter	52 — 5 1/2 —
Length over tube sheets	15 feet.
Grate area	82 square feet.
Heating surfaces :	
Firebox	1 150 square feet.
Arch tubes	67 — —
Fire tubes	788 — —
Fire flues	1 116 — —
Total evaporative	3 121 — —
Superheating	700 — —
Comb. evaporative and superheating	3 821 — —

Tender :	
Water capacity	16 000 gallons.
Fuel capacity	20 tons.
General data estimated :	
Rated tractive force :	
Cylinder, simple	85 000 lb.
Cylinder, compound	70 800 lb.
Auxiliary locomotive	18 000 lb.
Weight proportions :	
Weight on drivers ÷ total weight engine %	87.6
Weight on drivers ÷ tractive force, simple	3.5
Weight on drivers ÷ tractive force, compound	4.17

[313 : 625 .6 (.67)]

5. — Light Railways in the Union of South Africa.

Below are given certain statistics supplied by the South African Railways and Harbours :

Light railways within the Union of South Africa.

Mileages as at 30 June 1926 :

3 ft. 6 in. gauge :		
Laid with 60 lb. rails	2 094 miles.	
— 45-50 lb. rails	545 —	
— 45 lb. rails	361 —	
— 35 lb. rails	80 —	
		3 080 miles.
2-ft. gauge :		
Laid with 35-45 lb. rails	589 miles.	589 —
Total mileage		3 669 miles.

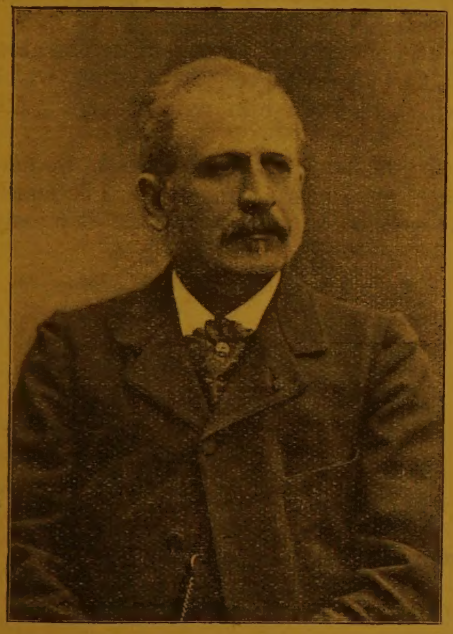
Engine power :

3 ft. 6 in. gauge (principal types in use) :	
6th, 7th and 8th class, tractive force	16 000 to 25 000 lb.
Branch line Garratts, tractive force	18 000 to 32 000 lb.
2-ft. gauge :	
Principal types in use	8 000 to 12 000 lb.
Garratts	16 000 lb.
Obsolete types	2 000 to 5 000 lb.
Density traffic to mile per working day :	
Total train mileage 3 ft. 6 in. gauge	4.3 trains to mile per diem.
— — 2-ft. gauge	2.8 — —
Freight tonnage (revenue traffic) :	
3 ft. 6 in. gauge	138 tons to mile per diem.
2-ft. gauge	73 — —

OBITUARY

ÉMILE HEURTEAU,

Director and former General Manager of the Paris Orleans Railway Company;
Former Member of the Permanent Commission of the International Railway Congress Association
Delegate to the eight Sessions from 1887 to 1922.



The news of the death on the 6 March last of Mr. Emile Heurteau, a Director and former General Manager of the Paris Orleans Railway, and former Member of the Permanent Commission of our Association, was received with deep regret.

Mr. Heurteau was one of the most prominent men in the Railway world.

He was born at Orleans on the 4 June 1848, and at 17 entered the « Ecole Polytechnique », where he displayed great brilliancy.

In 1875, after journeying in the Colonies on important business, he joined the Paris Orleans Company where his value was quickly realised. He was rapidly promoted to be head on the operating department, the most important position of the system, and in 1887 was made General Manager of the Company which he remained for 24 years.

His energy, ability, and authority were highly appreciated.

He was responsible for the construction of the d'Orsay station in 1900, and the electrification of the first line between that station and Juvisy in 1904.

He was as much interested in the well being of the staff as in operating questions, and largely developed the welfare work of the Company.

He was appointed General Delegate of the Administrative Council in 1910, and carried out the duties thereof for over 10 years : In 1921 he was made a Member of the Council.

Mr. Heurteau, whose activity was tireless, was also connected with many other important organisations and undertakings. He was Member of the Committee of Control of the principal Railway Companies, of the Higher Railway Council,

of the Syndicate of the Ceinture Railways, and of the Administrative Council of the Moroccan Railways and of the Railway from Tangiers to Fez. He was President of the Administrative Council of the « Forges et Aciéries de la Marine et d'Homécourt »; of the « Mines d'Anzin », of the « Mines d'Auderny-Chevillon », and of the « Consommateurs de Pétrole » Company. He was Vice-President of the « Compagnie de Navigation Sud-Atlantique » and Administrator of the « Crédit National », the « Union Hydro-Electrique » Company, etc.

He was Commander of the « Légion d'Honneur ».

Mr. Heurteau was nominated a Member of the Permanent Commission for the Milan Session of 1887, and acted until the Rome Session of 1922. He always shewed great interest in the Railway Congress Association and took an active part in its work. He took part in the preliminary work and the discussions of all the Sessions.

In particular he was President of the 5th Section (Light railways) at the Milan Session (1887); Member of the local organising committee for the Paris Congress (1889) and President of the 4th Section (General questions) at the Washington Session (1905).

The sound and practical intelligence of Mr. Heurteau, an engineer of great experience and knowledge, was always appreciated during the meetings of the Permanent Commission.

His enlightened judgment was of great value to the Congress Association, which will remember him with sincere gratitude.

In the name of the Association, we have sent our sincere sympathy to his family as well as to the Paris Orleans Company.

The Executive Committee.